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THE SOUND FIELD OF PULSED, PLANE RADIATORS*

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ABSTRACT

If a single voltage pulse is applied to a plane radiator in a large, rigid baffle, the pressure at a field point is shown to consist, in general, of a number of sequentially arriving pulses. These are associated with certain geometrical discontinuities of the radiating surface. Experimental confirmation of the theory is shown. A reciprocal type of behaviour applies to a receiving transducer in that a single pressure pulse incident on the receiving surface gives rise to an electrical output signal consisting of a sequence of pulses.

The phenomena described offer a fresh viewpoint for the understanding and calculation of acoustic fields. Several other implications are put forward, including a novel means of calculating mutual radiation impedances.

Introduction

Much is known about the sound field of radiators radiating into fluid media under continuous wave conditions; however a far less clear picture exists generally about the phenomena within the sound field of a pulsed transducer. I shall endeavour to clarify one particular aspect of this subject.

I shall restrict my attention to pulsed, plane radiators in plane, rigid baffles which are large in terms of wavelengths, and I shall show the sound field to be composed of a relatively small number of simple components.

For the class of radiators which form part of a closed surface whose dimensions are not large in terms of wavelengths, Kozina, Makarov and Shaposhnikov[1] on the one hand, and Junger and Thompson[2] on the other, have shown that when a pulse is applied, surface waves of significant magnitude are produced. These waves, which bear similarities to creeping waves, then provide contributions to the radiated field.

In my treatment, by assuming the baffle to be large, I shall be ignoring any diffracted components due to the surface wave mechanism, which components may be significant in a practical situation where the combined dimensions of

* This is the text of a paper presented in January 1968 at a symposium on "Acoustic Arrays" held at Birmingham under the auspices of the British Acoustical Society. The paper has also been issued as Admiralty Underwater Weapons Establishment Technical Note 331/69.

radiator and baffle are not large compared with the wavelength. My treatment will however be a useful approximation for a non-planar radiator of small curvature, providing of course that the dimensions of the radiator, together with any associated baffle, are sufficiently large.

An amplitude-modulated transmission pulse will be assumed and certain simplifying bandwidth assumptions are implicit in the treatment which require that the pulse be at least several cycles long but which otherwise do not materially affect the overall picture.

The Mathematical Solution

For a plane radiator vibrating at a single frequency in an infinite, rigid baffle, the pressure at a field point can be expressed after Rayleigh[3] as

$$p = i\,\frac{V\rho c}{\lambda}\,\exp(i\omega t)\int_S u(x,y,z)\,\frac{\exp(-ikr)}{r}\,dS \quad ,$$

where $u(x,y,z)\exp(i\omega t)$ represents the normal velocity on the radiating surface, S, per unit of voltage, V, applied to the radiator; c denotes the velocity of sound in the medium whose density is ρ; λ denotes the wavelength, ω the angular frequency and k the wavenumber; r is the range of the field point from each element of surface, dS.

The integral can be solved by a procedure which is analogous to that which I developed in a treatment of back-scattering and which was published in *Acustica* in 1962[4]†. I propose only to quote the end result but will first introduce some definitions. B(r) denotes the area of those parts of the radiating surface within range r of the field point (Fig. 1). The subscript w implies that each element of radiating surface is weighted by its local normal velocity, $u(x,y,z)$, so that, for example, $B_w(r)$ is the velocity-weighted value of B(r). When each element of radiating surface is weighted by the inverse of its range from the field point, B(r) changes to C(r); thus $dC_w(r) = r^{-1}\,dB_w(r)$.

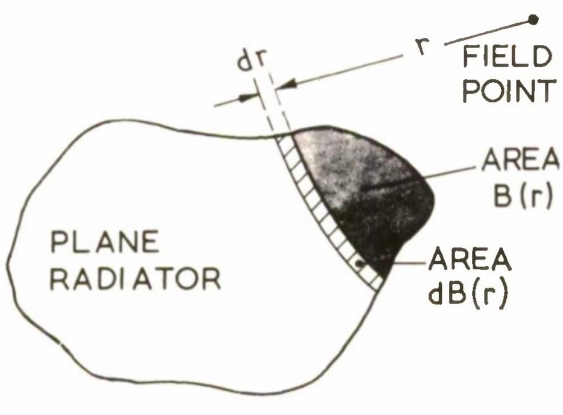

FIG. 1. Definitions for radiating surface.

† The treatment was also summarised in "A new interpretation of acoustic echo formation", A. Freedman, *J.R.N.S.S.*, 16, 63, 1961.

Assume that at ranges r_g (where $g = 1, 2, \ldots, f$) finite discontinuities occur in one or more values of the n^{th} derivative of $C_w(r)$ with respect to r (where $n = 0, 1, 2, \ldots$). Denote such discontinuities by $D(C_w, g, n)$. These discontinuities may either be due to the geometry of the radiator or to discontinuous distributions of the normal velocity over the radiating surface.

My treatment leads to the following expressions for the field pressure.

$$p = \sum_{g=1}^{f} p_g \quad ,$$

$$p_g = -i\,V\!\left(t - \frac{r_g}{c}\right)\frac{\rho c}{\lambda}\exp\left[i\omega\left(t - \frac{r_g}{c}\right)\right]\sum_{n=0}^{\infty}\frac{D(C_w,\,g,\,n)}{(ik)^n} \quad ,$$

where $V\left(t - \frac{r_g}{c}\right)$ denotes the envelope of the voltage applied to the radiator, on a delayed time scale.

These equations express the field in terms of the aforementioned discontinuities.

The frequency that occurs in the equation for p_g is the main transmission frequency.

We note that allowance has been made for non-uniform velocity distributions, and this means that the expressions shown are applicable to arrays as well as to single radiators.

Mechanisms of Transmission and of Reception

The above equations tell us that if a single voltage pulse is applied to the radiator, the pressure at a field point will consist, in general, of a number of sequentially arriving pulses. This is illustrated schematically in Figure 2. To the degree of approximation inherent in the treatment, the envelopes of these pulses will be scaled replicas of the envelope of the pulse at the radiator, and hence I have called them " transmission replica " pulses[5]. These pulses will appear to be generated at places where there are discontinuities in the velocity-weighted area function, $B_w(r)$ or its derivatives. The number, the relative spacings and the magnitudes of the pulses received at a field point are, in general, a function of the position of that point.

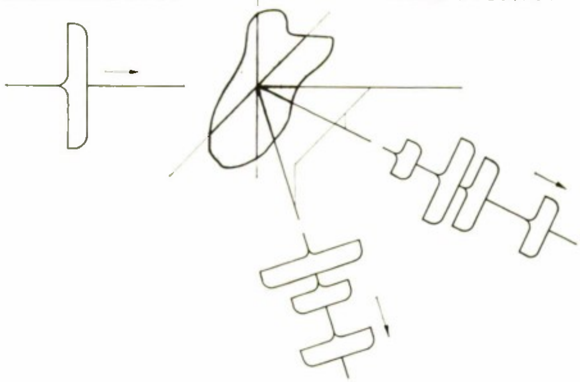

FIG. 2. Schematic representation of behaviour within sound field of a pulsed, plane radiator.

When these pressure pulses overlap in time, they add vectorially, and when all components are overlapping at steady level, the resultant is the C.W. field value.

That contributions to the field pressure should be received only from certain discrete ranges and not from the whole of the radiating surface may be seen to be plausible by the following argument. An element of the transmission pulse coming from the strip of radiator surface between ranges r and (r+dr) will arrive at the field point with the same phase ($\omega t - kr$) as that of the contribution which immediately preceded it from the strip between ranges (r−dr) and r, because ωt and kr increase in step. Thus, if there is no sudden change in $B_w(r)$ between an element of surface at range r and one at range r+dr, there will be no AC contribution to the pressure at the field point as the element of transmission pulse is received from successive parts of the radiator. A sudden change in $B_w(r)$ will however leave a net AC resultant of magnitude both proportional to this change and to the amplitude of the element of the transmission pulse. Contributions of the successive elements of that pulse will thus trace out a field component having the same envelope as the transmission.

For certain radiator shapes, some of the derivatives in B(r), and hence in C(r), exhibit infinite discontinuities; the series solution shown previously does not then apply. However, the treatment does indicate that wherever there is such an infinite discontinuity there will be a component contributed to the pressure at the field point, thereby giving at least qualitative information about the composition of the field. This is the case for non-axial points in the field of a circular piston, where my treatment shows qualitatively that the far field is made up of two transmission replica pulses of equal magnitude arising, respectively, at the near and far points of the piston. A schematic illustration of the time-variation of the far field is shown in Figure 3.

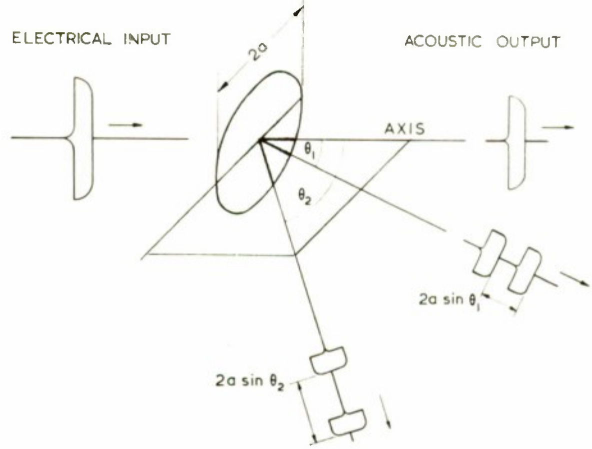

FIG. 3. Schematic representation of far field behaviour for a pulsed, circular piston.

Although I have so far spoken of phenomena associated with a transmitting transducer, a corresponding type of behaviour can be shown to hold for a receiving transducer[5]. Reciprocity applies to the pulsed situation in the following sense. If in one case a transducer transmits a pulse and the field is measured at a field point, P, while in the other case the same pulse is emitted at P and the output of the original transducer, now used as a receiver, is measured, then the structure of the output signal will be the same in both cases.

Thus if, as shown in Figure 4, a pulse of plane waves is incident non-normally on a piston-like, circular receiving surface, the electrical output signal will consist of two pulses. The time separation between these will equal the time difference between the incident pressure signal first reaching the near and far points of the receiving surface. For obvious reasons, I shall call these pulses " reception replica " pulses.

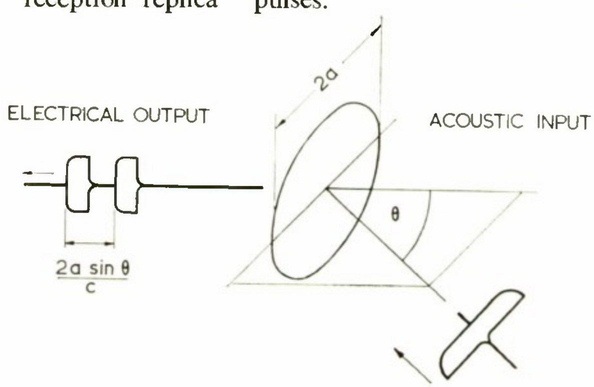

FIG. 4. Behaviour of a circular piston receiver for incident pulse of plane waves.

Compatibility with Results of Other Workers

The above conclusions concerning the field of a transmitting transducer are compatible with those of other workers.

In the following account it will be convenient to distinguish the position of a field point as follows. When the field point is located inside a right cylinder whose base is the radiating surface, I shall call it an interior point. A field point located outside this cylinder will be termed an exterior point.

The C.W. radiation from a plane piston has been examined by Schoch[6], and he concludes that the field at an interior field point is made up of a plane wave and of waves originating at certain discrete parts of the periphery. These parts will generally include the near and far points of the periphery and may include other peripheral elements. Schoch's definition of those parts of the periphery which contribute to these perturbing waves corresponds in my terminology to ranges where discontinuities in derivatives of B(r) occur. For an interior field point at a finite distance from the radiator there will always be a discontinuity in the first derivative of B(r) at the pole of the field point, and it can be shown that the term for $n=1$ in the first component of my series solution corresponds identically with Schoch's plane wave term.

For an exterior field point, the latter discontinuity in the first derivative of B(r) does not occur. Correspondingly, Schoch shows that there will be no plane wave component.

Schoch's treatment has been extended to the case of pulsed transmission by the Russians, Kozina and Makarov[7, 8]. They have dealt specifically with external field points in the plane of symmetry of radiators having an axis of symmetry, and have shown two field components for a circular piston and two for a square piston.

Another Russian, Kaspar'yants[9] has independently arrived at conclusions similar to those of Kozina and Makarov and has shown the presence of two components for a circular piston.

The Far Field of a Rectangular Piston

Applying my own series solution to the case of a rectangular piston, the structure at points in the far field is as indicated in Figure 5. For field points away from each of the central planes, there are four components of equal magnitude, each appearing to emanate from one of the four corners. Going to a central plane, the four components coalesce to two, which are associated with the near and far edges. On the acoustic axis, these two components coalesce to one, and the relevant discontinuity is associated with the whole surface.

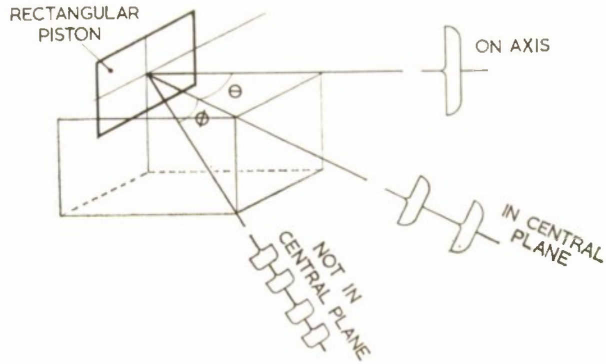

FIG. 5. Schematic representation of far field behaviour for a pulsed, rectangular piston.

The expression for each of the four transmission replica pulses is given by

$$p_g = \pm K_1 \, V\left(t - \frac{r_g}{c}\right) \exp\left[i\omega\left(t - \frac{r_g}{c}\right)\right] \frac{1}{2ka\cos\alpha \; 2kb\cos\beta}$$

$$\begin{cases} - \text{ for } g=1 \text{ or } 4, \\ + \text{ for } g=2 \text{ or } 3. \end{cases}$$

Adding the four components for steady state overlap yields the classical formula for the rectangular piston, as follows:

$$p = \sum_{g=1}^{4} p_g$$

$$= K_1 \, V \exp\left[i\omega\left(t - \frac{r_m}{c}\right)\right] \frac{\sin(ka\cos\alpha)}{ka\cos\alpha} \; \frac{\sin(kb\cos\beta)}{kb\cos\beta},$$

where $K_1 = i \dfrac{\rho c u}{\lambda r_m} 4ab$,

r_m = mean range,

α, β = direction cosine angles.

The C.W. level depends on the size of the radiator, the axial level being directly proportional to the radiating area. It is noteworthy that the magnitudes of the individual components are independent of the radiator's dimensions, and this is what we should expect from the mechanism outlined, as each geometrical discontinuity here depends upon a corner and not upon a length.

Figure 6 shows a comparison of the C.W. directivity and that of one of the two transmission replica pulses in a central plane. The lack of side lobes in the latter curve is the striking feature here. Indeed the side lobes of the C.W. curve are solely brought about by the vectorial addition of the two field components. The maxima of the side lobes correspond to in-phase addition of the components and are thus 6dB above their level. Similar remarks apply outside the central plane.

We thus see that the concept of field components I have presented yields a simplified way of understanding radiated fields. Instead of requiring to visualise the field as being made up of the integration of contributions from all over the radiator, we need only picture it as the sum of a small number of components.

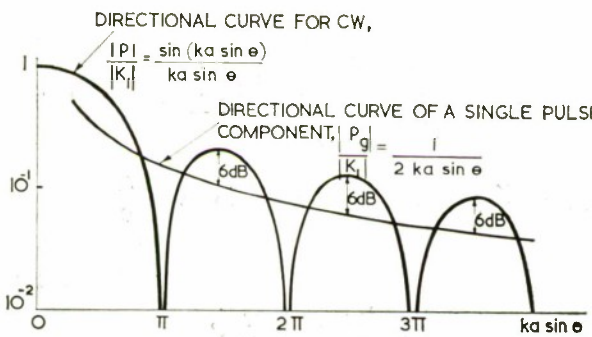

FIG. 6. Theoretical comparison, for a rectangular piston, of the C.W. and pulsed directivity curves in a central plane.

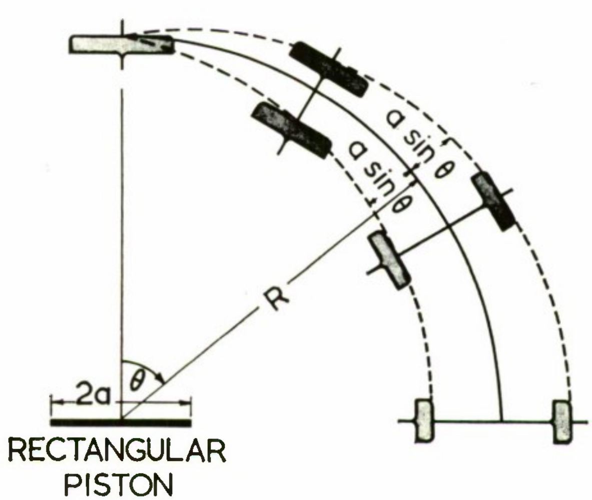

FIG. 7. Schematic representation of far field behaviour in a central plane of a pulsed, rectangular piston.

The monotonic directivity curve shown in Figure 6 for the individual field component is different in nature from directivity curves for the transient situation which have been presented by Polk[10] and by Mayo[11]; thus, some remarks are appropriate here to clarify the cause of the difference. Polk considered the far field in a central plane of a rectangular radiator, and subsequent important corrections to Polk's paper were made by Mayo.

On the basis of what I have said previously, the field for this particular situation is made up of two transmission replica pulses, as shown in Figure 7. The separation between start of the two components is 2a sin θ.

Presenting the same information on a Cartesian diagram and assuming, for simplicity, a rectangular pulse envelope of duration τ, the regions instantaneously covered by the two field components are shown in Figure 8. Two situations have been illustrated. On the left hand diagram, the pulse length is less than 2a divided by the velocity of propagation, c. Consequently it is short enough to provide resolution of the two components over those angles for which τ is less than 2a sin θ/c. It should be noted, however, that,

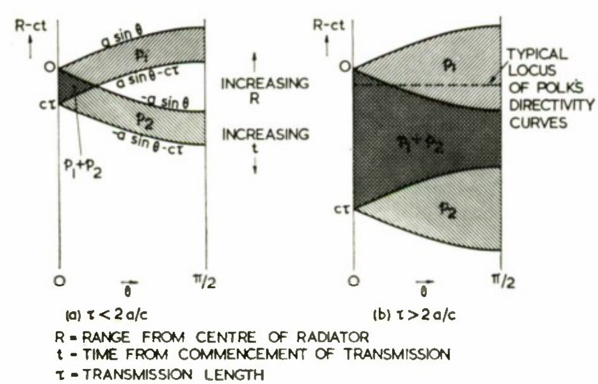

FIG. 8. Regions covered by replica transmission pulses in a central plane in the far field of a pulsed, rectangular piston.

as θ becomes small enough, there will always be some angular range over which there is overlap of the two components. On the right hand diagram, the pulse length is greater than 2a/c, consequently there is overlap of the two components at all angles. In the overlap regions, the CW level applies. The diagrams can be thought of either as corresponding to increase of range in the upwards direction or to increase of time in the downwards direction.

Thus, at a given value of θ, the locus of increasing time will be a downwards line, and passage down this line will, of course, correspond to passage through the sinusoidally varying instantaneous pressure levels. It is the magnitude of this pressure signal within a resolved field component which was shown in Figure 6 as a function of θ, and which presented a monotonic variation, devoid of side lobes.

Polk and Mayo, on the other hand, have presented directivity curves corresponding to a fixed moment of time and to a fixed range from the radiator centre; the loci involved are horizontal lines, of which a typical one is shown in Figure 8. A locus of fixed range from the radiator centre corresponds to a varying range from the near end of the radiator, which is the apparent source of the first field component. This varying range implies in turn a varying phase. Because Polk and Mayo's directivity curves apply to instantaneous field values, this varying phase is the reason why their curves show maxima and minima, giving the appearance of side lobes. Such directivity curves do not seem to be particularly useful, for any two curves corresponding to a fraction of a cycle time difference will differ from each other, and the positions of maxima and minima will be interchanged at time differences of at most a quarter of a cycle.

The Near Field of a Rectangular Piston

The general formula shown earlier for a transmission replica pulse applies also when the field point is in the near field, and so we will now take a brief, qualitative look at the near field structure of a rectangular piston.

For convenience of visualisation, we can use reciprocity and, for the moment, think of waves

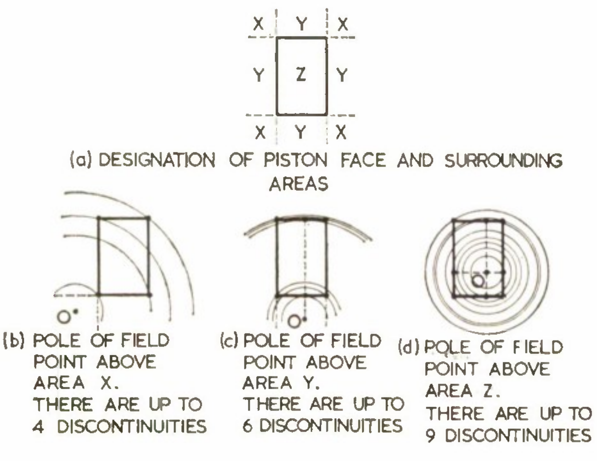

FIG. 9. Construction showing positions of sources of near field components for rectangular piston.

emanating from the field point. Equiphase strips of transducer face could be drawn as circles centred on the pole of the field point in the plane of the transducer. This enables us to visualise where geometrical discontinuities arise, as shown in Figure 9.

When the pole, O, lies in one of the areas designated as X in the upper diagram, there are, in general, four ranges at which geometrical discontinuities occur, each associated with one of the four corners of the piston. The magnitudes of these four discontinuities will not be equal, as is the case in the far field. When O lies in one of the areas designated as Y, there will, in general, be six points of discontinuity, namely at the four corners and also at two points where the sides of the piston are tangential to the wavefronts. Where O lies on the transducer surface, Z, there will, in general be nine points of discontinuity, one being at the pole itself.

Reverting to terminology in which the transducer is deemed to be a transmitter, we can say that, depending upon the location of the field point, the pressure field experienced at a point in the near field of a rectangular piston will consist of up to nine components.

Experimental Check on Theory

Let us next look at the conditions which must be satisfied for resolved transmission replica pulses to be observable experimentally. For simplicity we shall limit consideration to far field points in the central plane of a rectangular piston of length 2a. Firstly, the path difference, 2a sin θ, between the two pulses must be greater than Nλ, where N is the number of cycles in the transmission. Secondly, the level of the resolved pulses must not drop below the minimum detectable level, which we shall assume to be G times smaller than the axial level. The first condition corresponds to the requirement that 2ka be greater than $2\pi N/\sin\theta$; the second corresponds to the requirement that 2ka be less than $G/\sin\theta$. Regions in which these conditions are both satisfied are shown in Figure 10 for three combinations of N and G. Obviously, if $2\pi N$ is greater than G, it will not be possible to observe the resolved components.

Using a large rectangular transducer and working in the far field I have been able experimentally to resolve the field components in a central plane[12, 13], as shown in Figure 11. The single pulse at 0° gradually separates into two as the aspect angle increases and the picture at 20° shows the two fully resolved. At the latter angle the equality of amplitude of the two components and the reversal of phase predicted by theory can be clearly seen.

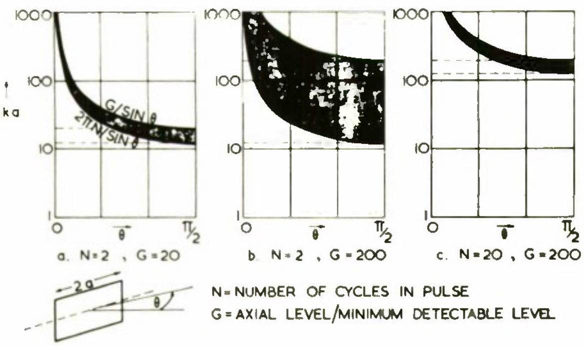

FIG. 10. Regions where resolved transmission replica pulses may be observed.

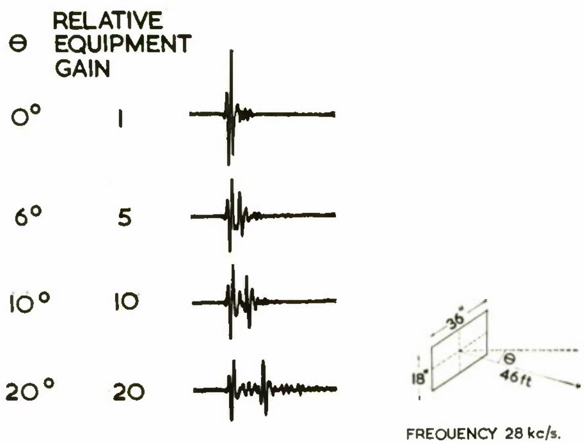

FIG. 11. Sound field of pulsed, rectangular transducer in central, horizontal plane.

Figure 12 shows measured curves of the C.W. directivity and of the directivity of a single pulse. Calculated points are also shown on the curve for a single pulse. The transducer was actually a rectangular array of abutting elements and there were evidently imperfections in it, for the C.W. curve becomes asymmetric and irregular from about the fourth pair of side lobes onwards. Therefore we cannot expect to check the pulse theory beyond the third pair of side lobes, and the theoretical points have only been plotted out to angles a little beyond this. At the angle corresponding to the first pair of side lobes, there was partial overlap of the two field components and the levels of the pulse directivity curve are about 5dB down on the C.W. curve, as against the 6dB predicted for a resolved field component. At the angles corresponding to the second and third pairs of side lobes, the components were resolved. At these angles the four measured pulse levels agreed with theory to within $\frac{1}{4}$dB.

Theory thus seems to have been satisfactorily supported by experiment.

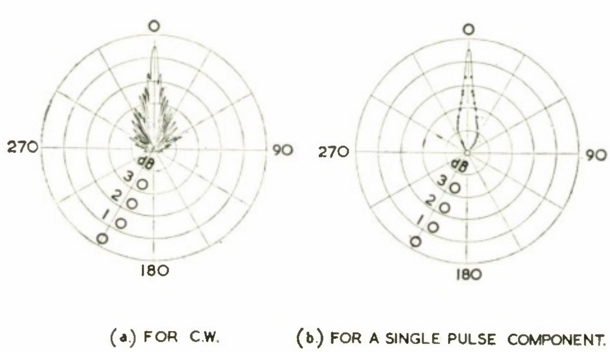

FIG. 12. Experimental comparison of C.W.- and pulsed-directivity of a rectangular transducer in central plane parallel to transducer length.

Radiation Impedance Considerations

Let us next consider the application of the principles I have described to the realm of radiation impedance.

Mutual radiation impedance calculations may be facilitated by our approach. For instance, at the top of Figure 13 is shown a system composed of two coplanar, rectangular transducers, one a transmitter and the other a receiver. This system is equivalent to a set of four directional point transmitters and four directional point receivers, as shown in the lower part of the figure. So instead of carrying out the usual type of double integration in order to obtain the mutual radiation impedance coefficient, one would sum the components at each of the four points representing the receiver due to the effective four sources representing the transmitter.

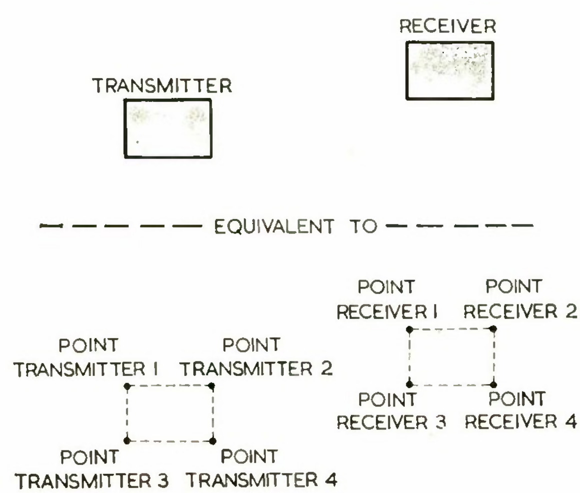

FIG. 13. An equivalence for obtaining the mutual radiation impedance between two rectangular pistons.

Next let us turn from a pair of elements to an array. In an array the steady state radiation load on any one element is made up of the vectorial sum of the contributions from all elements, the contribution from any one element of a planar array being itself made up of the contributions from its discontinuities. During the

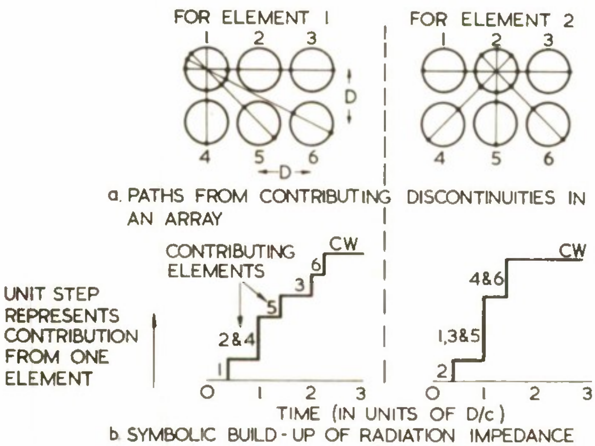

FIG. 14. Schematic representation of radiation impedance build-up in an array at start of a C.W. pulse.

transient period at the beginning of transmission of a C.W. pulse, the contributions from a gradually increasing number of discontinuities are received at any one element, and the steady state is reached when the total number is being received by each element. This is illustrated in schematic form in Figure 14 where, to keep the illustration simple, the agglomerated contributions of complete elements rather than of individual discontinuities have been shown symbolically. Although the stepped curves may give an impression of growth of magnitude of radiation impedance as more contributions become effective, it must be remembered that these contributions are vectors and may either increase or decrease the total magnitude. Evidently the time history of build-up of radiation impedance of an element in an array is a function of the position of that element within the array. At any given moment during the transient situation, the distribution of radiation impedances will differ, in general, from the distribution under C.W. conditions and, unless appropriate measures are taken, this may lead to undesirable effects in a practical equipment. The theory I have outlined seems to offer an approach for calculating the performance of an array during transients such as at switch-on or switch-off.

It should be noted that, providing an array velocity control measure is adopted of the type which makes the impedance of each element, when looked at from the acoustic face, much larger than the radiation impedance fluctuations, then such a velocity control measure should be effective during the transient periods as well as during the C.W. period. This contradicts a conclusion reached by Junger and Thompson[2].

My theory is also applicable to steered arrays and steered single radiators, although some extensions are needed to deal with steering by time delay, rather than by phase taper.

Pulse Structure in an Echo Location System

From the structure of signals associated with transmitting or receiving transducers, we can briefly extend our considerations to form some idea of the components that go to make up the signal in an echo location system. For simplicity we shall assume plane transmitting and receiving transducers and a rigid, scattering body whose dimensions are large in terms of wavelengths. For this case the signal structure will build up in the manner indicated schematically in Figure 15. Even in this simple case, one sees how complex the final signal is, and in a practical case there will be further components due to mechanisms we have ignored.

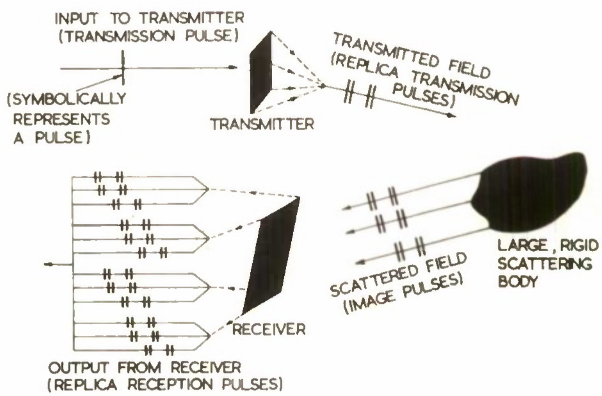

FIG. 15. Symbolic representation of pulse structure within an idealized " echo " detection system.

Possible Applications of the Theory

With the confidence engendered by the previously described experimental support of the theory, I shall, in conclusion, summarise some of the prospects which its application opens up.

(1) We may gain greater understanding of the structure of acoustic fields by appreciating the components of which they consist. Instead of abstrusely visualising a field as being due to the contributions from all over the radiator, we need only picture it as the sum of a small number of com-

ponents. As an example we saw that the sin X/X directivity curve in the central plane of a rectangular piston can be explained as the addition of two components, each of which has a simple form of directivity. This increased understanding of field structure may also facilitate obtaining fields having certain desired characteristics.

(2) We have potentially an additional tool for calculating near fields. For instance, the near field of a rectangular piston will consist of up to nine components and that of a circular piston of up to three. In principle, the field can be calculated by summing the components, although I do not yet know how difficult their evaluation will be.

(3) We can gain a better appreciation of the directional properties to be expected of a transducer as a function of transmission pulse length. For a central plane in the far field of a pulsed, rectangular piston, one of my illustrations (Figure 8) showed the angular regions covered by individual or overlapping transmission replica pulses as a function of time or range. Similar diagrams can be produced for non-central planes or for other radiators. Coupled with the relevant information about the individual field components, the directional properties for the pulsed situation can then be deduced.

It is evident that, when one is dealing with transmission pulse lengths which are too short to provide steady-state conditions, the normal concepts of side lobes and, hence, of side lobe levels break down. This emerges very clearly from a study I am currently making of the field of arrays steered by time delays. Hence it is necessary to devise fresh tools for the calculation of signal to reverberation and signal to noise ratios.

(4) Our theory yields a new way of calculating mutual radiation impedance, by summation of contributions at directional point receivers due to contributions from directional point transmitters.

(5) The concepts presented afford a possible approach for calculating the mutual radiation impedance effects in an array during the transient stages when the transmission is switched on or off.

The final two points are, for the moment, more tentative, as I am not a signal processing man, and I do not yet fully appreciate their implications. But I am presenting these two points with the idea that they may stimulate further thought.

(6) We may be able to gain additional insight on the limits of range resolution obtainable with a given system. As an example I will cite the case of an array steered by time delay, that is an array the whole of which is not energised simultaneously, but on which a short CW pulse is rippled along to the elements to achieve the desired steering. For the steering direction only, it may transpire that that system is analogous in range resolution to a broadband transmission of long duration.

(7) It may be possible to exploit the 6dB reduction relative to the CW side lobe levels which is provided by resolved transmission- or reception-replica pulses.

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A SIMPLE TECHNIQUE OF UNDERWATER HARDWIRE E.C.G. RECORDING

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Introduction

Increased emphasis on diving research to put man in the sea for commercial and industrial purposes through saturation diving, has produced a demand for a reliable and simple method of physiological monitoring during work excursions from the undersea habitat. While the ultimate aim is a reliable telemetric radio transmitted system, in the foreseeable future, use will be made of hardwire monitoring of physiological parameters. This results from the practice of diver connection by an umbilical cord to the habitat, through which run gas supply, suit heating water, voice communication, and a light multicore cable for both routine and research monitoring. It is considered important that not only should an E.C.G. trace demonstrate pulse rate, but also clearly show a wave form, from which can be diagnosed clinical pathological states should these arise. A single abnormal wave form may provide sufficient early warning of diver distress that simple pulse monitoring would not necessarily indicate at that stage. The purpose of the present system is to demonstrate the practicability of obtaining readable E.C.G. records from a working diver through a continuous cable to a small E.C.G. recording device.

Equipment

The electrodes found most suitable were M.R.C. silver disc electrodes, (Fig. 1) dimensions of which are diameter—1·25 inches (30 mm), thickness—0·025 inches (0·6 mm) and with a disc contact area of 0·5 inches (12 mm). These were attached to the skin by double-sided adhesive tape. A sponge pad was inserted in the cavity of the electrode, im-

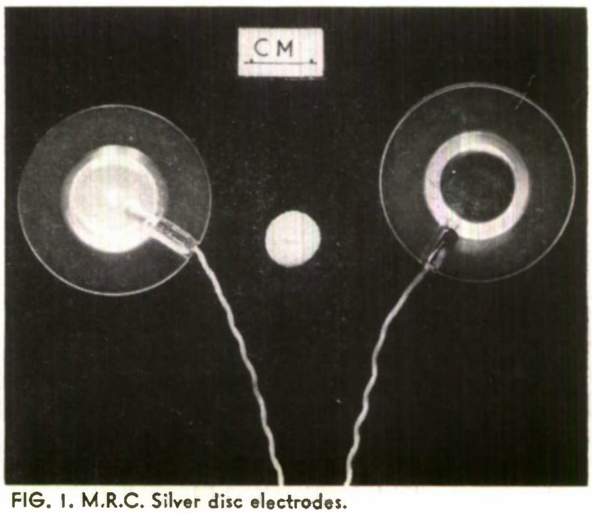

FIG. 1. M.R.C. Silver disc electrodes.

pregnated with Cambridge electrode jelly to which had been added a small preparation of chlorhexidine (Hibitane). At increased pressures, up to 800 feet in our experiments, excellent tracings were obtained. This was due to good skin contact being made by compression of the flexible electrode cavity and flattening of the pad onto the skin. However, unlike electrodes with cavities entirely filled with conductive jelly, none of this was forced out under the sealing ring, and all electrodes remained fully watertight in 100 feet of water.

To connect the electrodes to the cable, we trimmed the fine wire, which was integral with the silver contact discs, to three inches and soldered an electrode to each conductor of a 3-core cable, a fourth electrode being joined to the outer metal screen. This latter electrode, corresponding to Right Leg, was, as convention, used for the amplifier earth. The soldered joints were encased in moulded silicone rubber, giving robustness and full waterproofing.

In the prototype system used, the electrodes were connected directly to 300 feet of P.V.C. sheathed 3-core collectively screened cable of 0·0003 sq. ins. cross section (0·0072 sq. mms.). In the production system, a water tight plug is being incorporated to allow the diver to disconnect himself from the greater bulk of cable on leaving the water. In Fig. 2, the cable can be seen to be wound in a figure-of-eight sequence. This prevented cable kinking on paying out or retrieving, common with a cable drum.

We have used two different recording machines, the Honeywell Cardio View and the Devices C.I.A. single channel recorder. The advantages of these are portability and battery operation, and can be used in situations where a mains supply is unavailable or unreliable, such as the foreshore or on board a vessel with no reliable generator. There is no danger of mains shock and resistors need not be interposed in the circuit. The E.C.G. signal strengths obtained were so good that no amplifier external to the recorder was required. In fact, the gain was reduced by half in all cases.

Technique

The technique of application of electrodes is important in order to obtain satisfactory E.C.G. tracings. We have found the best routine for skin preparation is an initial cleansing with Teepol, followed by shaving, degreasing with acetone or spirit and finally abrasion with fine emery paper. It had been suggested that this abrasion followed by wearing the electrodes for periods of many days might produce inflammation and skin infection but this has not been found, possibly due to the use of Hibitane in the electrode jelly. Meticulous skin preparation gave excellent results and

FIG. 2. Recorder, cable and electrodes

also ensured that the double-sided adhesive tape gave a most secure attachment, remaining adherent and watertight for up to four days.

The electrode positions chosen were the best compatible with a good tracing under all conditions of the dive, including heavy underwater exercise. The most commonly used position was with two electrodes (R.A. and R.L.) sternally and a third (L.A.) on the anterior axillary line, and the record taken on lead 1. The fourth electrode (L.L.) was not used on the present series of investigations but has been available for clinical E.C.G. recordings using limb leads. Tracings were taken at either 5 mm/sec. or 25 mm/sec., the latter allowing a greater degree of clinical diagnosis (Fig. 3).

Recordings

The quality of tracing has been very good under conditions that had proved troublesome to other workers. The electrodes required no additional securing material, apart from small pieces of adhesive strapping to hold the cable bight to the body, even when worn under a wet suit without front entry[1], and they proved perfectly watertight at pressure. Extraneous oceanic parasitic interference[2] has been eliminated by using cable screening and an amplifier earth from the subject. We also found that no artefacts arose when the cable was rolled across the sea bed in heavy swells and none due to electrode movement

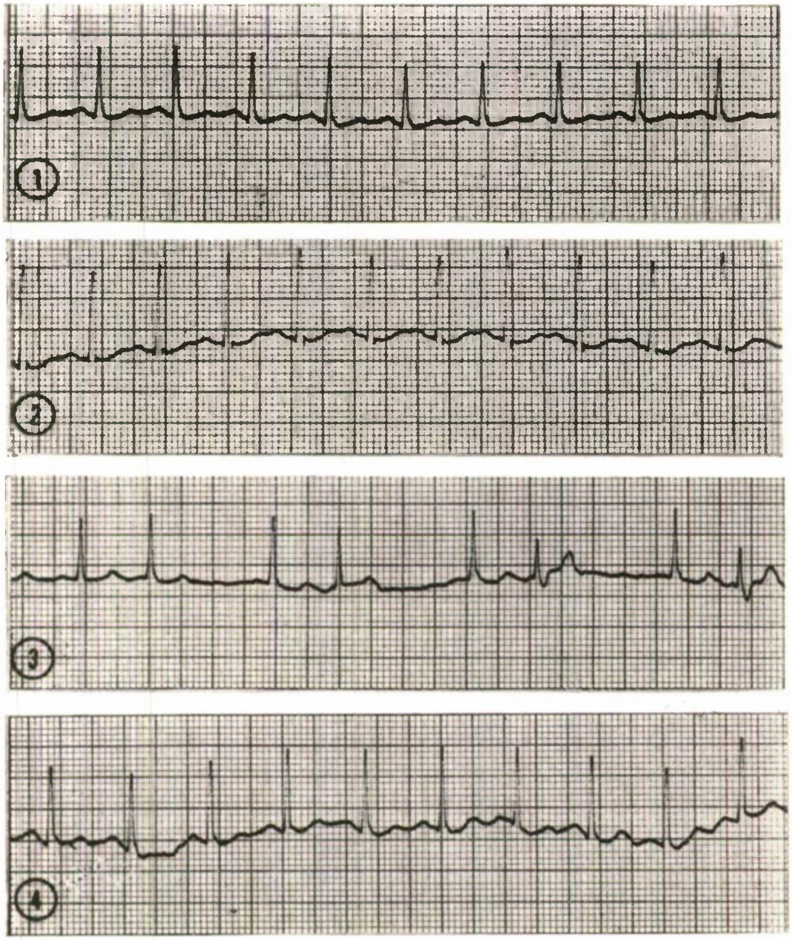

FIG. 3. Sample E.C.G's
(1) taken out of water using 300 feet cable
(2) taken in open water of 15 feet depth
(3) taken in 100 feet water (apnoeic bottom drop—note arrhythmias)
(4) during hard work in 100 feet water

were seen[3]. The only major difficulty we encountered was that of excessive baseline wander on the Honeywell recorder, when exercising. This was absent on the Devices machine. Typical E.C.G's from a variety of conditions are shown in Fig. 3.

Acknowledgements

We would like to express our appreciation of the help and co-operation given us by our colleagues, and especially Lieutenant Commander M. Todd, R.N. and our willing subjects from the Submarine Escape Training Tank, H.M.S. Dolphin, Gosport, and Mr. Roy Belcher of the Photographic Department, Royal Naval Physiological Laboratory, Alverstoke.

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EFFICIENT UTILISATION OF 1620 CORE AND DISK STORAGE FOR LARGE FORTRAN PROGRAMS DEALING WITH LARGE MULTI-DIMENSIONAL ARRAYS

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DESCRIPTION OF SYSTEM AND OPERATING ENVIRONMENT

System

A 20k IBM 1620 with single 1311 Disk Drive; Monitor I. Card and paper tape input and output; Benson-Lehner on-line plotter.

Environment

The installation is situated in the Department of Nuclear Science and Technology at the Royal Naval College, Greenwich. It is used for design study work, processing data evolving from experimental work, and as a general teaching aid. Virtually all programming is in FORTRAN IID, and one week courses are offered at regular intervals throughout the year. The computer is operated on an ' open shop ' basis; a punch machine operator is the only person fully engaged on computer work. System management, and advisory, instructional and program debugging services are provided by two members of the staff, who are only able to devote part of their time to computer work. The normal mode of operation of the machine is by stacked input through the card reader.

Introduction

Much of the work involves relatively simple calculations, and the resulting programs can frequently be accommodated in the core store. However, larger problems often make it necessary to use the program overlaying facilities of the Monitor System, and store intermediate data on the Disk.

This paper was presented at the 1969 meeting of the European Region of COMMON, held in Rotterdam, 26th-27th September. COMMON is an organisation for the users of IBM digital computers.

Linked Programs

The Monitor Manual indicates that linked mainline programs, using the CALL LINK and COMMON statements, provide the answer to the large program problem. With some large programs, it has been necessary to divide the calculation into 15 or more linked parts. The word ' link ' suggests a chain of programs which are processed linearly. However, program logic frequently results in complex branching between linked programs, necessitating frequent overlaying. In this situation, it became apparent that loading a linked program from the permanent storage cylinders of

disk to core storage often requires between 20 and 30 seconds. Under these conditions, when execution time for individual linked programs is short, total running time can be more dependent upon overlay times than actual computation.

Mainline Program Calling Subroutine Subprograms

Earlier experience had shown that Subroutine Subprograms sharing an area of core storage through the use of a LOCAL control record only require a very short overlay time. The time consuming task of retrieving the local Subprograms from the permanent storage cylinders is done only once, before Mainline program execution starts, the Monitor placing the Subprograms in the disk working cylinders.

It was decided to make use of this rapid overlay facility by writing what were previously linked programs as a set of local Subroutine Subprograms called by a short controlling Mainline program. With this method, it only takes about one second to load a Subprogram from the disk working cylinders to core. The consequent saving in total processing time can be considerable.

Appendix A shows initial typewriter output during the compilation and execution of a mainline program which uses 10 Subroutine Subprograms.

APPENDIX A—MAINLINE PROGRAM

```
‡‡FORX5 01
      DEFINE DISK (10,3000)
      COMMON NR, NGR, IG
      GO TO 2
    1 A=ATAN(EXP(LOG(A)))
      RECORD(IG)A
    2 READ 7,MIX
    7 FORMAT(I1)
      DO 8 NCELL=1,MIX
      CALL CX1MK2(NCELL)
      CALL CX1A2
      DO 3 IG=1,NGR
      CALL CX2
      CALL CX3
    3 CALL CX4
      CALL FN1
    4 DO 5 IG=1,NGR
      CALL FN2
    5 CALL FN3
      CALL FN4A
      IF(IG)3,8,4
    8 CALL MAT(NCELL,MIX)
      CALL EXIT
      END
```

$\bar{0}0590$ CORES USED

$\bar{1}9987$ NEXT COMMON

END OF COMPILATION

EXECUTION

*LOCAL, CX1MK2, CX1A2, CX2, CX3, CX4, FN1, FN2, FN3, FN4A, MAT

MAIN $\bar{0}7500$ $\bar{0}0590$ LOADED

14 $\bar{0}8090$ $\bar{0}1258$ LOADED

06 $\bar{0}9348$ $\bar{0}1342$ LOADED

02 $\bar{1}0690$ $\bar{0}1158$ LOADED

01 $\bar{1}1848$ $\bar{0}0850$ LOADED

FLIPER $\bar{1}2698$ 00600 LOADED

CX1MK2$\bar{1}3300$ 05496 LOADED

CX1A2 $\bar{1}3300$ $\bar{0}6222$ LOADED

CX2 $\bar{1}3300$ $\bar{0}5798$ LOADED

CX3 $\bar{1}3300$ $\bar{0}6032$ LOADED

CX4 $\bar{1}3300$ $\bar{0}6556$ LOADED

FN1 $\bar{1}3300$ $\bar{0}5352$ LOADED

FN2 $\bar{1}3300$ $\bar{0}5402$ LOADED

FN3 $\bar{1}3300$ $\bar{0}4438$ LOADED

FN4A $\bar{1}3300$ $\bar{0}5136$ LOADED

MAT $\bar{1}3300$ $\bar{0}5862$ LOADED

The following points are of interest:—

The only library subroutines which are loaded to core are those used in the Mainline program. Statement 1 and the statement which follows it are dummies, which ensure that the named subroutines are present in core during the execution of the Subprograms which require them.

Most of the Subprograms are called by statements which contain no list of arguments. This is because communication between Subprograms is achieved through COMMON statements (see Subroutines CX3 and CX4).

APPENDIX B—SUBROUTINE CX3

```
      SUBROUTINE CX3
      DIMENSION R(49), SIGT(49), GROW(49),
     1 TAUROW(49)
      COMMON NR, NGR, IG, P11
      COMMON IPROW, IPCOL, ISIGTR, ICON,
     1 ITAUG
      EQUIVALENCE(GROW, TAUROW),
     1 (GROW(1), PSTAR), (GROW(2), PDASH)
     2 (TAUROW(48), RI) (TAUROW(49), SIGI)
C     TO GET RI AND SIGI AT TAIL
      IND=ISIGTR
      FETCH(IND)SIGT, R
      IND=ITAUG
      DO 72 I=1, NR
      M=I+1
      II=I-1
      FETCH(IND)TAUROW
```

```
         Stage 1
      IND=IND-5
      FIND(IND)
      RI=R(I)
      SIGI=SIGT(I)

         Stage 2
      LOOP=NR-I
      IF(LOOP)8, 8, 1
    1 DO 70 J=M, NR
      RJ=R(J)
      RAT=RI/RJ
      TERM=(1.-RAT*RAT)**0.5
      TERM=ATAN(RAT/TERM)/RAT+TERM
      RAT=R(J-1)/RJ
      IF(I-J+1)67, 69, 69
   67 DELT=TERM-RAT*EXTERM
      GO TO 68
   69 DELT=TERM-1.570796*RAT
   68 EXTERM=TERM
      G=0.5*SIGT(J)*RJ*TAUROW(J)*DELT
   70 GROW(J)=1.-EXP(-G)
C     GROW(J)OVERWRITES TAUROW(J)

         Stage 3
      IF(II)7, 7, 8
    7 RE=RI
      GO TO 3
    8 PSTAR=RII*GSTAR/(2.*SIGI)*(RI*RI
        -RII*RII)

         Stage 4
      RAT=RII/RI
      RATSQ=RAT*RAT
      X=1.-RATSQ
      XX=X*X
      XXX=XX*X
      ALOGRX=LOG(1./X)
      EAL=1.+.44479204*X+.85099193E-1*XX
        +.40905094E-1*XXX
      EAL=EAL+(.24969795*X+.08150224*XX
        +.01382999*XXX)*ALOGRX
      CAL=1.3862944+.09793289*X+.54544409E
        -1*XX+.32024666E-1*XXX
      CAL=CAL+(.5+.12475074*X+.60118519E
        -1*XX+.10944912E
        -1*XXX)*ALOGRX
      RW=1.+RAT*RATSQ-(1+RATSQ)*EAL
        +X*CAL
      RW=RW*RI/X
      PSIG=1./(1.+3.*SIGI*RW)
      RE=PSIG*RW+(1.-PSIG)*RI*X
    3 X=RE*SIGI
      IF(X-3.5)73,73,74
   73 P11ORE=.29991*X+2.95455*X**2+1.8879*
        X**3+.99821*X**4
      P11ORE=P11ORE/(.22621+2.65415*X+4.09779
        *X**2+2.37943*X**3+X**4)
      GO TO 75
   74 P11ORE=1.-.5/X+.09375/X**3-.058595/
        X**5
   75 IF(II) 4, 4, 5
    4 P11=P11ORE
      GO TO 71
    5 PDASH=P11ORE-PSTAR*GSTAR

         Stage 5
      IF(LOOP) 76, 76, 71
   71 GSTAR=GROW(M)
   76 RECORD (IND) GROW
      RII=RI
   72 FIND (IND)
      RETURN
      END
```

APPENDIX B — SUBROUTINE CX4

```
      SUBROUTINE CX4
      DIMENSION GLAST(49), GTHIS(49),PCOLJ
        (49), PCOLT(49), PROWI(49)
      COMMON NR, NGR, IG, P11
      COMMON IPROW, IPCOL, ISIGTR, ICON,
        ITAUG
      EQUIVALENCE(PCOLI, PROWI), (GTHIS(49),
        (GTHIS(48), RI), (PCOLJ(49), SIGI)
      SIGJ),(PCOLJ(48),RJ),(GLAST(48),RII),
        (GTHIS(1), PSTAR), (GTHIS(2), PDASH)
      INDG=ITAUG
      INDPRW=IPROW
      INDPCI=IPCOL+5
C     COLUMN I NOT FETCHED FIRST LOOP
      IND=INDG
      FETCH(IND)PROWI
C     TO INITIALISE THE 49 FIELDS OF PROWI,
        AND GET R AND SIG AT TAIL
C     *
C     OUTER LOOP (FOR EACH ROW) STARTS—
        ROWSUBSCRIPT IS I
C     *
C     *
      DO 1 I=1, NR
      II=I-1
      IF(II) 2, 2, 30
    2 IND=INDG
      FETCH(IND)GTHIS
      PROWI(1)=P11
      PROWI(2)=1.-P11
      DO 84 J=3, NR
      JJ=J-1
   84 PROWI(J)=PROWI(JJ)*(1.-GTHIS(JJ))
      DO 184 J=2, NR
  184 PROWI(J)=PROWI(J)*GTHIS(J)
      IPCJF=INDG
C     SO THAT FIRST FETCHES OF PCOLJ IN
      INNER LOOP BRING THE G ROWS WITH
C     THEIR ASSOCIATED R AND SIGT WHICH
      ARE RETAINED FOR FUTURE USE AS R
```

```
C        J AND SIGJ WHEN PCOLJ IS RECORDED.
         AND THEN FETCHED AS PCOLI, WHICH
C        IS OVERWRITTEN BY PROWI LATER
         GO TO 31
      30 FETCH(INDG)GLAST, GTHIS
         INDG=INDG-5
         IPCJF=IPCOL
         FETCH(INDPCI)PCOLI
         IF(I-NR)14, 32, 32
      14 QI=SIGI*RII
         IF(QI-3.5)98, 98, 99
      98 TOP=.29991*QI+2.95455*QI**2+1.8879*QI
           **3+.99821*QI**4
         QI=TOP/(.22621+2.65415*QI+4.09779*QI**
           2+2.37943*QI**3+QI**4)
         GO TO 100
      99 QI=1.-.5/QI+.09375/QI**3-.058595/QI**5
     100 RAT=RII/RI
         RATSQ=RAT*RAT
         RATSQ1=1.-RATSQ
         GLI=1.-GLAST(I)
         RTSQQI=RATSQ*QI
         PBAR=RTSQQI*GLAST(I)/RATSQ1
         TI=GLI*(RTSQQI+RATSQ1*(PSTAR-
           PBAR))
         GAMMA2=TI/RATSQ1
         GAMMA1=1.-PDASH-PSTAR+GAMMA2
      32 DIV=SIGI*(RI**2-RII**2)
         SUM=O.
         EXRJSQ=O.
      31 IPCJR=IPCOL
C        *
C        INNER LOOP (FOR EACH COLUMN)
         STARTS, COLUMN SUBSCRIPT IS J.
C        *
C        *
         DO6J=1, NR
         FETCH(IPCJF)PCOLJ
C        FROM G FIRST TIME, SEE NOTE
         UNDER 184
C        *
         FIND(IPCJR)
         IF(II) 13, 13, 12

      12 GLASTJ=GLAST(J)
         GTHISJ=GTHIS(J)
         IF(J-I)7, 8, 9
C        I.E. BELOW, ON, OR ABOVE DIAGONAL
       7 RJSQ=RJ**2
         P=PCOLI(J)*SIGJ*(RJSQ-EXRJSQ)/DIV
         SUM=SUM+P
         EXRJSQ=RJSQ
         GO TO 11
       8 PITOP=PSTAR-SUM
         P=PITOP*GLASTJ+PDASH
         PTOP=PITOP-PITOP*GLASTJ
         GO TO 11
       9 GAM1=GAMMA1*GTHISJ
         GAM2=GAMMA2*GLASTJ
         PBIT=PTOP*GLASTJ
         P=PBIT+GAM1-GAM2
         GAMMA1=GAMMA1-GAM1
         GAMMA2=GAMMA2-GAM2
         PTOP=PTOP-PBIT
      11 PROWI(J)=P
      13 PCOLJ(I)=PROWI(J)
         IF(SENSE SWITCH 2)43, 6
      43 PRINT 120, IG, I, J, PROWI(J)
     120 FORMAT(I3, 2I5, E17. 8)
       6 RECORD(IPCJR)PCOLJ
C        *
C        INNER LOOP ENDS
C        *
C        *
       1 RECORD(INDPRW)PROWI
C        *
C        OUTER LOOP ENDS
C        *
C        *
         RETURN
         END
```

When using this method of communication, the programmer must make his own overlap checks, since the Monitor overlap checks are only based on the COMMON requirements of the Mainline program.

Looping around groups of Subprograms is easily controlled in the Mainline program.

All the Subprograms are listed in the LOCAL control record.

Note the manner in which programs are loaded. First, the Mainline program, the library subroutines and the 'local' loading subroutine, FLIPER, are loaded to the core. Then, the subprograms are loaded, not to the core, but to the upper working cylinders of *disk*. (Note: the space required by FLIPER increases with the number of Subprograms being used).

Execution of the Mainline program proceeds in the normal way, with FLIPER bringing each Subprogram from *disk* when it is required.

Storage and Manipulation of Arrays and Matrices on Disk

The program shown in Appendix A calculates the neutron flux distribution and average cross-sections for a complex cell of a nuclear reactor, and is based on a previous program set which used the LINK overlay method. Solution of the problem requires the cell to be divided into a number of separate physical regions; the original program permitted a maximum of 12 regions.

The basic mathematical task of the program is to develop and solve sets of simultaneous equations, each set containing one equation for each region. The original program was therefore required to operate on 12 × 12 matrices, which

were held in core. The matrices placed heavy demands on core storage, and the original program required 16 links.

The new program was written to achieve a more accurate solution by dealing with a larger number of cell regions, and consequently, larger matrices. The matrices are held on *disk,* and the program deals with individual rows or columns as one dimension arrays. In the interests of speed, and economy of core storage in FETCH and RECORD lists, the entire arrays are always handled in *disk* storage operations. However, because the program is sometimes required to deal with a smaller number of regions than its maximum capacity, it is necessary to initialize all arrays with valid numeric fields to ensure that no 'wild' group marks are present. Initialization can be achieved either by setting all elements to zero, or, perhaps more rapidly and economically, by fetching an array of identical size from *disk.*

Use of EQUIVALENCE Statement

In addition to creating in-core working areas, EQUIVALENCE statements can sometimes be used to effect economies by reducing subscripting and the length of input/output lists.

(See Subroutine FN3).

An EQUIVALENCE statement can be used to enable a number of arrays or single variables (ISIGT, ISIGF, *etc.*) to be referred to as a single array, IDADDR. Subsequently, it is possible to record all the arrays with a very simple RECORD statement. In subsequent Subroutines, the arrays can be fetched by a correspondingly simple FETCH statement, providing an identical EQUIVALENCE statement is present in the program.

In the Subroutine CX3, the triangular matrix, G, is developed from another, TAU, which is held on *disk.* The matrices are dealt with by the program in rows, as GROW and TAUROW.

The calculation required two other quantities, R(I) and SIGT(I), which have different values for each row. These values are fetched as two arrays. Values of PSTAR and PDASH are also calculated for each row; these quantities would normally have been required to be stored in core as two arrays. However, an EQUIVALENCE statement is used to place the calculated values of PSTAR and PDASH in the first two elements of the row, GROW, to which they relate.

To effect further economies in the next Subroutine, CX4, which operates on the G matrix and the 4 row quantities R(I), SIGT(I), PSTAR and PDASH, Subroutine CX3 uses the EQUIVALENCE statement, and the statements RI=R(I), SIGI=SIGT(I), to place these quantities in the 48th and 49th elements of each GROW.

The following table, in which each line corresponds to a stage marked in Subroutine CX3, illustrates the manner in which a single array is used to fetch a row of the matrix TAU, and store and record the corresponding row of matrix G, together with its 4 quantities. The array is referred to as TAUROW or GROW in the program, and the table shows operations on the 3rd row of the matrices.

Stage ↓	*Elements of GROW or TAUROW*									
	1	2	3	4	5	6	7		48	49
1	–	–	–	$T_{3,4}$	$T_{3,5}$	$T_{3,6}$	$T_{3,7}$		–	–
2	–	–	–	↓	↓	↓	↓		R_3	S_3
3	–	–	–	$G_{3,4}$	$G_{3,5}$	$G_{3,6}$	$G_{3,7}$			
4	P^*_3	–	–							
5	↓	P'_3	–	↓	↓	↓	↓		↓	↓

Key: T=TAU, R=RI, S=SIGI, P*=PSTAR, P′=PDASH.

The GROW is finally recorded. In the next Subroutine, CX4, the rows are fetched as GTHIS; appropriate EQUIVALENCE statements make all quantities immediately available to the program. In Subroutine CX4 a square matrix, P, is calculated; the program records the matrix in both row and column form to facilitate operations in later Subroutines.

Matrix Inversion and Equation Solution

Subroutine FN3 contains a routine for inverting a 49 $\times$ 49 matrix, A, which is stored on *disk*. After inversion, the routine solves the equations against the constants in array C. Rows of the matrix are stored sequentially on *disk* as 49 element arrays, the *disk* address of the first row being held in IAROW(IG). The routine is contained between statements 30 and 70, and the solutions are stored as array PHI. Matrix size, NR, is variable.

APPENDIX B—SUBROUTINE FN3 EXTRACT

```
      SUBROUTINE FN3
      DIMENSION AROWI(49), AROWK(49),
        PHI(49), C(49), DRSQ(49)
      EQUIVALENCE (AROWI, PHI), (AROWK,
        DRSQ)
      COMMON NR, NGR, IG, RNR, AMBDA,
        C, NVERT, EXAMDA
      DIMENSION ISIGT(4), ISIGF(4), ISIGR(4),
        ISIGS(4), ISUMP(4), NPCOL(4), IPHI(4),
        IAROW(4), IDADDR(34)
      EQUIVALENCE
        (IDADDR, ISIGT), (IDADDR(5), ISIGF),
        (IDADDR(9), ISIGR), (IDADDR(13), ISIGS),
        (IDADDR(17), ISUMP), (IDADDR(21),
        NPCOL), (IDADDR(25), PHI), (IDADDR(29),
        IAROW), (IDADDR(33), IDRSQ), (IDADDR
        (34), IC)
      IND=556
      FETCH(IND)IDADDR
      GO TO(30, 40), NVERT
C     NOW INVERT THE MATRIX A
   30 INDI=IAROW(IG)
      DO 100 I=1, NR
      FETCH(INDI)AROWI
      INDI=INDI-5
      FIND(INDI)
      RECXX=1./AROWI(I)
      AROWI(I)=1.
      DO200 J=1, NR
  200 AROWI(J)=AROWI(J)*RECXX
      RECORD(INDI)AROWI
      INDK=IAROW(IG)
      DO 100 K=1, NR
      FETCH(INDK)AROWK
      INDK=INDK-5
      FIND(INDK)
      IF(K-I)300, 100, 300
  300 XX=AROWK(I)
      AROWK(I)=0.
      DO 400 J=1, NR
  400 AROWK(J)=AROWK(J)-XX*AROWI(J)
  100 RECORD(INDK)AROWK
C     NOW SOLVE
   40 INDK=IAROW(IG)
      DO 70 K=1, NR
      FETCH(INDK)AROWK
      FIND(INDK)
      XPHI=0.
      DO69J=1, NR
   69 XPHI=XPHI+AROWK(J)*C(J)
   70 PHI(K)=XPHI
```

General Economical Programming

In the preparation of the program, the existence of the original proved version afforded opportunity for careful study with the object of eliminating repetitive calculations and operations, particularly is the range of DO loops.

Subscripted variables incur penalties, both in the amount of core storage required to describe their location, and the processing time required to calculate their addresses. In the inner loop of subroutine CX4, where quantity GLAST (J) is used 4 times, economies are effected by preceding its use by the statement GLASTJ=GLAST(J), and then using GLASTJ to describe the quantity.

Unnecessary use of library subroutines and fixed point exponentiation should be eliminated. The routine from subroutine CX2 shown in Appendix B was originally written:—

```
51  DO  53  IR=1, 11
    XY=XIJ ** (IR-1)
    XX=XY * LOG (XIJ)
    POLY 2= .....
53  POLY 3= .....
```

The new routine only makes one entry to the LOG subroutine, and develops values of XY by 11 progressive multiplications, rather than 11 entries to the lengthy exponentiation operation.

APPENDIX B—SUBROUTINE CX2 EXTRACT

```
   51 XY=1.
      ALOGX=LOG(XIJ)
      DO 53 IR=1, 11
      XX=XY*ALOGX
      POLY2=POLY2+XY*A2(IR)+XX*B2(IR)
      POLY3=POLY3+XY*A3(IR)+XX*B3(IR)
   53 XY=XY*XIJ
```

Conclusions

At the start of this project, it had seemed unlikely that the original 16 link program, which was able to handle a 12 region problem, in six hours, could effectively have its capacity increased. Operation on large *disk* stored matrices could

be expected to create a prohibitive increase in execution time (roughly proportional to the square of the number of regions).

However, careful study of the problem led to the development of more efficient procedures, of which some have been described. Better numerical methods were also developed, but they have not been discussed because they only relate to the particular problem.

The new program, containing only 10 subroutines, now handles a 12 region problem in one hour, 15% of the original time, and has the capacity to handle a 47 region problem in about 12 hours. It is, perhaps, worthy of note that, with this problem, the 20k IBM 1620 is running a 60,000 digit program operating on 300,000 digits of live data. The Subroutine Subprograms and data fully occupy some 18 of the 23 working cylinders of *disk*.

The program has already been run on a number of occasions, totalling over 50 hours of computer time. To achieve similar runs on the original program, if it had the capacity, would have taken over 300 hours. The five man-weeks of effort which were required to develop the new program have, therefore, yielded very significant returns, both in straight financial terms, and in terms of the speed with which the results were made available. This example demonstrates that considerable benefits can sometimes be derived from critical re-examination of frequently used programs, particularly when the original programmer's prime discipline does not lie in the computing sphere.

JOROTO—A NEW ROTARY DIESEL ENGINE

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SUMMARY

This invention combines known practical, scientific and engineering applications, resulting in a compact workable project which is simple, economically sound and of sufficient engineering advance to make similar existing projects obsolescent.

In this particular instance it is thought that the patented Simple Rotary Diesel Engine can possibly replace the conventional pistoned internal combustion engine, using the diesel application; it can also be quickly adapted for petrol use.

Introduction. This rotary diesel engine has no pistons, connecting rods, valves or crankshaft, but simply consists of a static stator, with an offset revolving rotor that has moving self-sealing rotor blades which are spring energised. It has open inlet and exhaust ports, with one spring loaded combustion outlet valve. The cost of manufacture will be small, several units can be positioned on a common rotor or torque shaft to produce greater power and a balanced firing order. One firing or power stroke is achieved for each revolution in a single engine unit. Auxiliary components *viz.* diesel fuel pump, diesel injector, governor *etc. etc.* are proprietary items.

Several major engine manufacturers have shown interest and at present negotiations are being carried out with one particular diesel engine manufacturer. The Board of Admiralty have given the inventor permission to exploit this patented engine commercially.

Description. The engine has few moving parts, it incorporates the diesel principle, with compression ignition in the region of 500 lbs. per sq. in. with diesel fuel of about 150°F flashpoint.

The engine (Figs. 1 & 2) consists of a stator, and is a bored casting or fabricated flanged cylinder with open inlet and exhaust ports without valves. This stator has bolted or welded to it a compression

chamber carrying the diesel fuel standard injector. Offset from the centre line of the stator casing is a rotor with two slots in the same plane. In these slots are fitted two in number blades or vanes, these are assembled with guide rods and heavily weighted springs (Fig. 3).

As the rotor is offset to the stator, when revolved or rotated the blades or vanes have the effect of moving in and out of their respective slots, pressure assistance is maintained for edge contact sealing by sealing strips pressurised by helical coil compression springs, thus with rotation the volumes of air in front of the compression blade is rapidly compressed. The compressed gas is by-passed through an inlet pipe (Fig. 4) a non-return plate or disc valve to a compression chamber which houses a fuel injector.

The blade moves on, through rotation and when just immediately past the explosion or combustion port, the injector fires and the outlet valve opens and the combusting gases force down the blade or vane and thus rotates the rotor spindle or shaft. When combustion is complete the inert gases are naturally vented or exhausted through open ports, the blade continues in movement (anti-clockwise for purposes of description) due to shaft rotation and again compresses the air ready for ignition. Thus one firing stroke is achieved for every revolution, followed by exhausting and inletting all within one revolution.

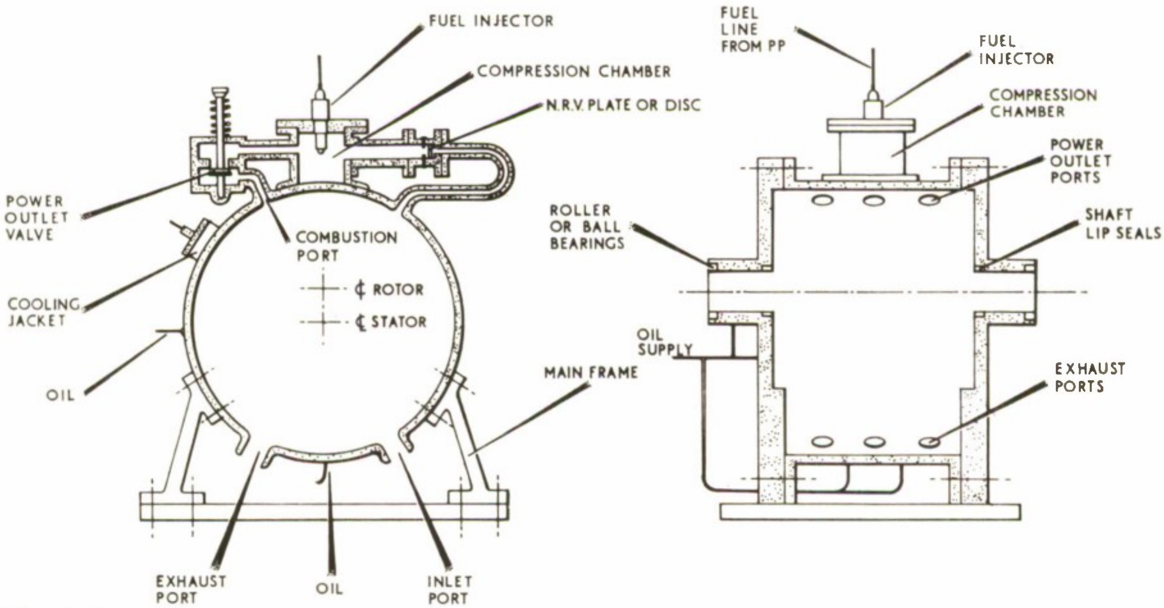

FIG. 1. Stator.

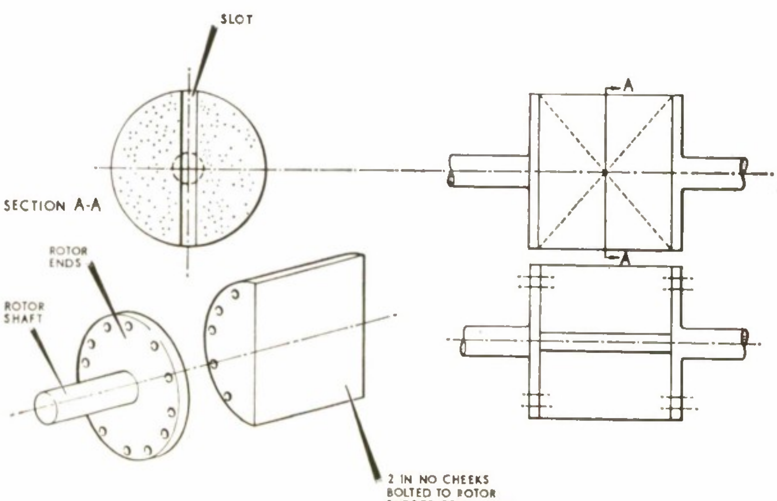

FIG. 2. Section of Rotor.

Mounting.

Any number of these units can be assembled on a common shaft to provide a balanced firing order.

Sealing.

Gland sealing on rotor shaft through stator casing is provided by commercial shaft lip-seals. The sealing of rotor and rotor blades is achieved by suitably designed compression U-type metal lip-seals.

Cooling.

The simple design allows for suitable cooling around the stator casing with pump and radiator. Bled heat can be used for lubricating oil temperature control.

Outlet or Combustion Valve.

This is a simple ICE spring loaded valve, cam and tappet rod operated from the main or rotor shaft.

Diesel Injector.

Standard injectors are used.

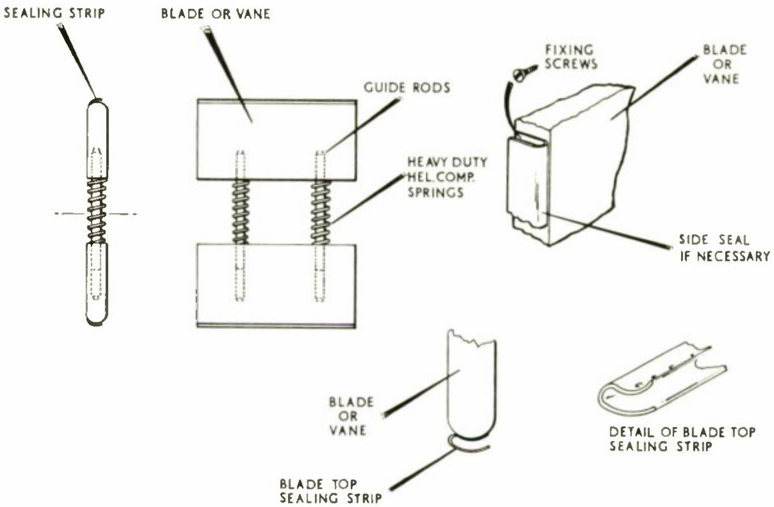

FIG. 3.
Rotor Blades

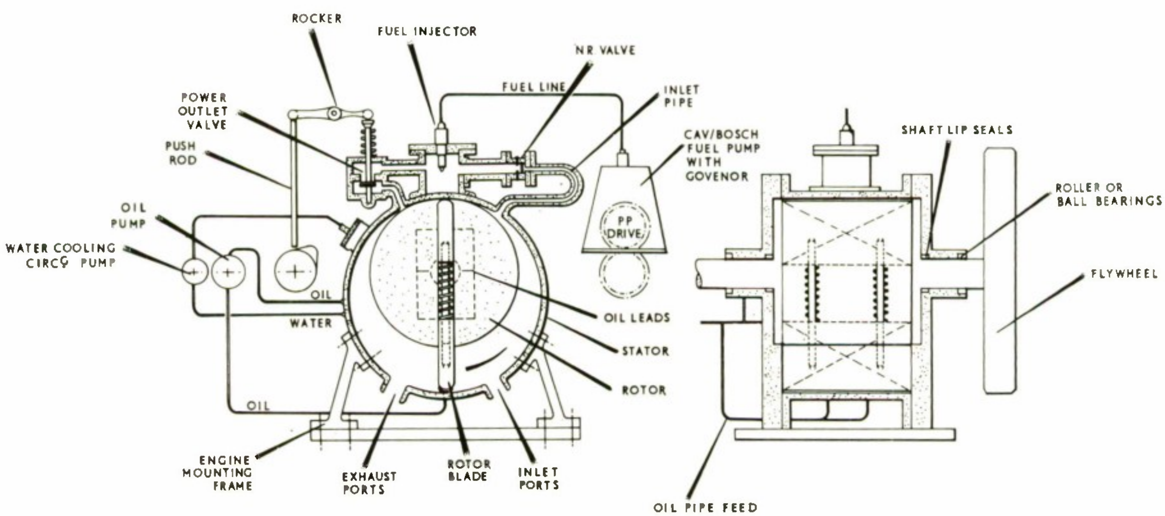

FIG. 4. Rotary Engine Assembly

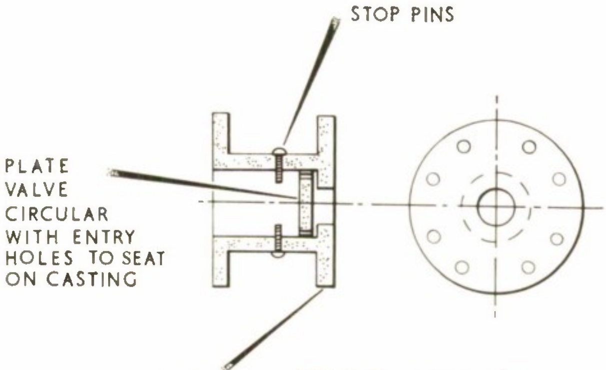

FIG. 5. Non return valve

Diesel Oil Fuel Pump.
A standard CAV/Bosch pump is used, driven by belt or gearing from main rotor shaft.

Governor and Speed Control.
Standard oil controlled governor is used with ratchet or rack and gear pinion for speed control.

Alternative to Diesel Layout.
The same basic assembly is used, but with change-over from diesel injector to a petrol carburettor and ignition system, a petrol engine can be brought forward.

Materials.
Conventional materials and metals etc. are envisaged for the engine construction *i.e.* (a) Stator casing cast iron, mild steel, cast brass *etc.* (b) Rotor in aluminium or mild steel or cast iron. (c) Rotor blades in stainless steel or phosphor bronze. (d) Rotor shaft in mild steel or stainless steel.

Lubrication.
Lubrication is provided by suitable drillings or ports to rotor, rotor shaft, rotor blades, using an established oil *i.e.* 1ML-L-9,000 diesel lubricating oil.

Bearings.
Roller or ball bearings are used to support and allow rotation of the rotor in the rotor casing. No thrust bearings are required as all thrusts are radial in nature but air bearings are envisaged for production models.

Fly-wheel and Starter Ring.
Would be provided for kinetic energy and starting routine.

Manufacturing Costs.
It is envisaged that fairly low research and development costs will arise because of simplicity of overall engine design using off the shelf materials and accessories. Final costs would therefore be small.

Weight/H.P.
This ratio can be very light as compared with conventional ICE design.

Future Use. The engine can be used for example in motor vehicles, as power units for boats or for driving electric generators.

Design Notes:

Compression Chamber

(a) The flange receiving the fuel injector to be a screwed fitting to allow a variable in compression.
Let x=compression factor, then $x \times 15$ p.s.i. =total compression

$$x=\frac{\text{Vol. air on compression side of blade}}{\text{Vol. compression chamber}}$$

(b) The compression chamber, inlet and outlet pipes to be heat insulated.

(c) The inlet and outlet pipes to be kept to a minimum length, sketch is illustrative only.

Bearings

(a) Air bearings are envisaged for Rotor Shaft, or

(b) Traditional roller or ball bearings.

Balanced Firing Order

(a) Several of these compression units can be assembled angularly equi-distant on the common Rotor Shaft to produce a balanced firing order.

(b) One compression unit would be effective.

Friction

(a) Low coefficient of friction figures can be achieved by suitable design and choice of materials in slides of Rotor and Rotor blades.

(b) Steel rollers inserted in Rotor slots would achieve low coefficient and seal at the same time.

Rotor Blades

(a) Blade thermal conditions will be controlled by suitable design and provision of cooling ducts.

(b) Lip sealing by spring strip application can be changed to a suitable sealing/compressive material, *i.e.,* Ferrobestos, Nylon, *etc.*

Stator

(a) Dimensions are envisaged as
Diameter = Length = say 10 inches
but upward variables are permissible.

(b) Power outlet valve; this is of large proportion equated to engine size to minimize gas flow restriction.

(c) The inlet non-return valve has six in number entry holes, diametrically and equi-spaced to suit seat diameter to allow through air passage to compression chamber.

Rotor

(a) Manufacture could be of machined assembly, machined casting, or prefabricated welded and machined assembly.

(b) Suitable materials can be selected from low-cost bronze, aluminium or ferrous.

Lubrication

(a) Adequate lubrication will be provided as shown in sketches, with temperature control maintained by coolant water flow.

(b) To be linked with control governor.

Cooling

(a) Adequate jacket cooling will be provided, linked with lubrication system, effected by simple coolant pump.

(b) For marine application sea-water circulation is envisaged.

Engine Rotation

(a) Sketch drawings show anti-clockwise rotation, but clockwise rotation is achieved by change over of inlet and outlet pipe connections.

(b) Engine speed controlled by Governor and Trip mechanism.

Engine Output

(a) Approximately 60 - 70 b.h.p. at 6000 r.p.m. using a 10 inch diameter stator, *i.e.*, about half the size of a conventional I.C.E.

Conclusion. Several advantages arise in the design of this rotary engine, when compared to the conventional piston engine.

1. Continuous uninterrupted flow rotation as opposed to piston engine stop and go linear motion, working a crankshaft through connecting rods.
2. Higher speeds and higher torque figures are obtainable in the design, particularly as one power stroke exists for one revolution.
3. Unloaded rotor or driving shaft, as compared with big end bearing loadings and crankshaft loadings in piston engine.
4. Spring assisted rotor blades are self-compensating for wear and seal at the same time.
5. Few moving parts keep maintenance and replacement costs very low.
6. Ease of manufacture and simplicity of assembly keep costs low, as few fine manufacturing tolerances are required. It is considered that this patented rotary engine could lead the way to a major breakthrough in the field of internal combustion engine design.

Admiralty Experiment Works

In January, AEW was visited by Dr. D. Owen, M.P., the Permanent Under Secretary of Defence for the Royal Navy, and later by Vice Admiral M. P. Pollock, Flag Officer of Submarines. Also Mr. C. E. Sherwin, the Director of Warship Design, Mr. W. G. Perry, the Deputy Director Design Constructions A and Mr. K. G. Evans, the Superintendent of N.C.R.E., came to discuss Establishment liaison. Visitors to A.E.W. during February included Dr. W. Petrie, Chief of Canadian Defence Research Staff, Admiral Sir John Frewen, C-in-C Portsmouth, and Mr. R. C. H. Russell, Director of the Hydraulics Research Station. Mr. D. S. Watson, D.C.S. (Naval), and Mr. S. Bolshaw, Scientific Adviser to DG Ships visited A.E.W. in March for general discussions and later Mr. S. J. Palmer, D.D.G. Ships also visited for discussions.

On 2nd January a symposium, sponsored by the British Acoustical Society, was held at the Department of Mechanical Engineering, University College, London on " The Sea as a Random Process ", at which Mr. J. E. Conolly and Mr. D. T. O'Dell from A.E.W. lectured on " Some Problems Associated with the Practical Computation of Wave Spectra ", and " Some Problems Associated with the Measurement of Wave Height in Manoeuvring Tank Work ", respectively.

The British Towing Tank Panel meeting held at Clydebank on 28th January was attended by Mr. A. J. Vosper (Chairman) and Mr. P. W. Hunt (Secretary).

Mr. M. S. Chislett attended the conference, Oceanology International '69, held at Brighton during February, and in March he visited the Technische Hogeschool, Delft, and the Hydro-og Aerodynamisk Laboratorium, Lyngby, to exchange ideas on the design and construction of a horizontal planar motion mechanism.

PROBABILITY, JUDGMENT AND MIND
2—The Nature of Mind Part 3

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THE PSYCHO-PHYSICAL WORLD

"These disturbing phenomena seem to deny all our usual scientific ideas; how we should like to discredit them! Unfortunately, the statistical evidence, at least for telepathy, is overwhelming."—A. M. Turing.

This concluding section of the paper is not intended as a brief for the existence of extra-sensory perception; E.S.P. (short for extra-sensory perception) is already accepted by many reputable and sceptical scientists—albeit sometimes reluctantly. The opening quotation is taken from a section in "Modern Experiments in Telepathy"[1] which describes the hostile reactions of some scientists to the seemingly conclusive experimental evidence supporting telepathy. But, as Professor Eccles[2] has said "If as men of science we reject these experiments, it should be done on the basis of established errors in their execution or interpretation. Such errors have evaded years of careful scrutiny by unsympathetic critics". Our purpose, therefore, is not to convince anyone that extra-sensory perception exists; neither is it our intention to distinguish or elucidate the conditions necessary for it to occur—this is the undertaking of current research in the field. Rather, our ambition in this section is to outline some of the theories developed to explain E.S.P. and the conditions under which it takes place and to show how they relate to and support the three "suggestions" offered in the first section to extend Dr. I. J. Good's theory of subjective probability[3, 4]. To recapitulate briefly these are (1) a psychical universe exists, (2) it is of a "collective" or "universal" nature and (3) both psychical and physical universes are different aspects of the same "transcendental monism". Each of the three main areas of E.S.P., *i.e.* telepathy, precognition and psycho-kinesis (P.K.) has features which, taken with the theories just outlined from experimental particle physics and from several schools of psychological and psycho-analytic thought, add support to our suggestions.

Telepathy and precognition are perhaps the two phenomena most thoroughly investigated as yet. Physical radiation theories of telepathy are open to serious criticisms but theories of an underlying unity to mind obviate some of these difficulties. These theories may originate in psycho-analysis (Jung), or be based on ancient mystical or religious traditions such as those outlined by Kenneth Walker in "The Conscious Mind"[5]. Many theories of precognition deal with occasional glimpses by the unconscious mind of pre-existent universes or thought patterns, or of co-existent and parallel universes, similar to those mentioned by I. J. Good[6] and by S. G. Soal and F. Bateman[1]. There has been little acceptable research carried out on psycho-kinesis but this does not mean it is unimportant. In the previous section reference was made to Professor Eccles' suggested mechanism for the firing of certain critical neurons in the brain by P.K.[1, 2, 7]. Eccles has said of the P.K. experiments of J. B. Rhine[8] "These experiments as described leave little room for doubt that very slight changes can be produced by some minds on moving physical objects such as dice . . ." (Comments are to follow from Professor Broad on levitation). Clearly any one of these phenomena is of importance to someone wishing to lay odds or assign probabilities.

The apparent lack of connection between the brain and E.S.P. is described by Dr. Grey Walter as follows: "The power of conditioning, as demonstrated by laboratory experiments, the cult of Yoga, and the ailments of hysterical origin, seem to share the same mechanisms. In hypnosis, again, we see how wide and deep is the dominion of the brain over all other organs and functions. But

in this state the rules of conditioning seem to be waived. There is no reward or punishment, no dignified succession of neutral and specific stimuli . . . The device by which the hypnotist contrives the plasticity of dreams without the apathy of sleep is a matter for further study and experiment . . . To many people the evidence of the power of brain over body is so impressive that it seems to extend itself quite naturally to another category altogether, the influence of mind over matter, and to suggest an indefinite merging of such physiological curiosities as we have outlined into some transcendental realm of spiritual experience. We must confess at this stage that no study of brain activity has thrown any light on the peculiar forms of behaviour known variously as second sight, clairvoyance, telepathy, extra-sensory perception and psycho-kinesis ".

Dr. Grey Walter dismisses the ideas of those seeking a material basis for otherwise unaccountable behaviour; namely (a) that the electrical activity of the brain might be the mechanism whereby information could be transmitted from brain to brain, and (b) that the electrical sensitivity of the brain might be a means of communicating with some all-pervading influence. Quite apart from any philosophic objection there may be to such an argument, he writes, the actual scale and properties of the brain's electrical mechanisms offer no support for it. He continues " Even if we ignore these physical characteristics, the observations reported on extra-sensory phenomena seem to exclude any such approach; for there is no evidence that screening of the subject, or distance between sender and receiver, have any influence on the nature or abundance of the effects described. Furthermore it seems to be one of the cardinal claims of workers in this field that a signal may be received before it is transmitted. If we accept these observations for what they are said to be, we cannot fit them into the physical laws of the universe as we define them today. We may reject the claims of transcendental communication on the grounds of experimental error or statistical fallacy, or we may withhold judgment, or we may accept them gladly as evidence of spiritual life, but it does not seem easy to explain them in terms of biological mechanism ".

Let us consider some of the alternatives offered in this quotation from Dr. Grey Walter's book " The Living Brain "[9]. Some comments which arise are as follows:—

(a) In continuation of our opening quotation, Professor Turing writes: " The idea that our bodies move simply according to the known laws of physics together with some others not yet discovered, but somewhat similar, would be one of the first to go ". As Professor Turing (among others) admits that the statistical evidence is overwhelming, the inference would seem to be that mind *is* distinct from brain and *does* operate under different laws.

(b) Soal and Bateman give vigorous refutations of suggestions of statistical fallacy in a section devoted especially to statistical considerations[1].

(c) Transcendental communication *was* accepted by Professor Hardy in the Gifford Lectures on Natural Theology of 1966. Hardy saw extra-sensory perception, together with contemplative prayer, as a channel of communication between man and the numinous. He considered E.S.P. as proven beyond doubt. If these postulates are true, Professor Hardy concluded, they ought to be confirmable by experiment; and in his last lecture he announced the founding of a research unit for exactly this purpose at Manchester College, Oxford. It should be pointed out that his conclusions are based on Hardy's own insistence on a rigorously empirical approach, in keeping with Lord Gifford's request that the lecturers should treat Natural Theology " as a strictly natural science, without relevance or reliance upon any . . . so called miraculous revelation ".

(d) With regard to transcendental communication and experimental error, we can consider the words of Professor Broad[11]: " I assert, without the slightest fear of contradiction from anyone who has studied the records, that there is no *direct* evidence for any of the New Testament miracles which is comparable in weight to the evidence for some of the alleged miracles of modern mediumship. For the levitation and other supernormal physical phenomena of D. D. Hume we have the contemporary autographic testimony of Sir William Crookes, one of the ablest experimental scientists of the nineteenth century, who was deliberately investigating the phenomena in his own laboratory under controlled conditions. It would be merely impudent to suggest that the *direct* evidence for the resurrection or the ascension available to us here and now is comparable with this ".

(e) Again, the experimental techniques and statistical significance of the results of E.S.P. experiments are accepted by no less a sceptic (in other fields) than Professor Eysenk[12], who writes: " Taking together the work of Rhine, Tyrrell, Soal, and other investigators, such as Carrington . . . there

appears to be little possibility of denying the existence of precognition. However much such a conclusion may be against our ingrained habits of thought, the experimental rigour and the statistical adequacy of the experiments are such as to make the criticism impotent . . . "

(f) We can hardly call the views of Sherrington, Eccles, Burt, Wigner, Jung, Stafford-Clark, Eysenk, Hardy and Sir Julian Huxley (to name only a few) "glad acceptance of spiritual life". They are grave and considered opinions from eminent men of learning which have been forced upon them by facts and observation. Neither are they withholding judgment—the only alternative left according to Grey Walter—these are, on the contrary, carefully weighed, sober, *positive* judgments. (It is interesting to note that Dr. Grey Walter chooses to use not the word "mental" but prefers to use "spiritual"). We can add that even Freud was willing to allow for the effect of telepathy, occasionally in dreams[13]. Although he would not commit himself definitely, he left little doubt that he did believe that telepathy *could* play a part in dreams. He wrote: "Among these conjectures the most probable is, I think, that in occultism there is a core of facts which have hitherto not been recognised, and round which fraud and phantasy have woven a veil which it is hard to penetrate. But how can we even approach this core? At what point can we grasp the problem? It is here, it seems to me, that the dream comes to our aid by suggesting to us that we should prick out the theme of telepathy from all the confused material that surrounds it".

(g) Sir Julian Huxley appraises the situation concerning telepathy in the following way: "Experiments such as those of Rhine and Tyrrell on extra-sensory guessing, experiences like those of Gilbert Murray on thought transference, and the numerous sporadic records of telepathy and clairvoyance suggest that some people at least possess possibilities of knowledge which are not confined within the ordinary channels of sense-perception. Tyrrell's work is particularly interesting in this connection. As a result of an enormous number of trials with apparatus ingeniously designed to exclude all alternative explanations, he finds that those best endowed with this extra-sensory gift can guess right about once in four times when once in five would be expected on chance alone. The results are definite, and significant in the statistical sense, yet the faculty is rudimentary: it does not permit its possessor to guess right all the time or even most of the time—merely to achieve a small rise in the percentage of right guessing. If, however, we could discover of what this faculty really consists, on what mechanism it depends, and by what conditions and agencies it can be influenced, it should be capable of development like any other human faculty".

(h) Soal and Bateman criticise scientific materialism. According to this view, human beings are not just material aggregates which behave according to the laws of quantum theory. The brain is, in this view, no more than an electrical switchboard of amazing complexity but without an operator. That external agents can operate this switchboard (and even be exchanged) is shown strikingly by an experiment reported in 1965. José Delgado, of Yale, transmitting electrical stimulation by radio signals caused animals to walk, climb, yawn, sleep, mate, switch emotions, and so on at command. Most spectacularly a charging bull was made to stop short and trot peacefully away. (A fate similar to this befell the wretched scientist Weston in C. S. Lewis's "Voyage to Venus").
The deadly sequel to the philosophy of scientific materialism, Soal and Bateman say, is that human beings have no ethical or moral responsibility for their actions since the latter are determined by the laws of physics. They make the point that human beings at least *appear* to be acting with purpose and striving towards future goals. It must appear to any dispassionate observer that humans, far from being exquisite pieces of mechanism, set before themselves ideals which they try to realise and for which they are often prepared to die. (We shall see later how Sir Charles Sherrington elaborated on a theme similar to this—associating Altruism and loves for Truth and Beauty with the evolution of life on this planet, the Planet's Aim as he called it, and with Natural Theology).

(i) We have seen enough of current theories in particle physics on the nature of matter, space and time to suggest that it is becoming increasingly difficult to claim that E.S.P. cannot be fitted into the laws of physics.

There is one duallistic theory of the mind which has been put to the test experimentally with negative results: It has same bearing, also, on a question of concern to R. G. Braithwaite[4] *i.e.* whether beliefs can be added to the rational corpus on an

all or nothing basis. The theory is that of Whately Carrington in which he introduces the concept of "psychons". Carrington supposed that mental events such as ideas and images exist in their own right, and are not synonymous with chemical and electrical events which take place in human brains. He looked on a mind as consisting of a large number of elementary constituents—sense data and images. Images are of the same nature as sense data, only less vivid and constant, and Carrington used the word "psychon" to cover both sense data and images. Resemblances can be seen to the theories of Burt, Cantor and Sherrington.

Certain tensions and relations exist between the members of a psychon system, and this is what we mean when we say that the system is conscious. These groups of psychons in which tensions are particularly strong at a given instant would constitute the normal consciousness of the mind, while the more quiescent groups would constitute its "subconscious".

Carrington further supposed that the subconscious psychon systems of different minds have no relation to physical space, and that they form one large system or common mind. This concept of an all-embracing subconscious mind composed of individual minds is an old one which goes back to the mysticism of ancient India. Carrington made it sound more plausible in a scientific sense by basing it on Bertrand Russell's atomic theory of consciousness. It has a flavour of Gestalt theory (see footnote) and of Jung, also, and was published in 1945. (If we follow Wheeler's and Einstein's example and view particles as incredibly minute alterations in the ultra-microscopic geometry of space or as variations in the intensity of fields, with the *field* as the only *reality*, monism and pantheism manifested as Gestalt and Jungian forms become apparent in very many places.)

Carrington next assumed that the laws of associations of ideas operate within the common "subconscious" mind just as they do in individual minds: Soal's and Bateman's experiments were designed to exploit this assumption. As we have said, no significant results were obtained but Soal and Bateman suggest that there is plenty of room for modification and improvement on the experimental technique. They point out that among other things, there are doubtless other influences, quite as potent as contiguous association, which govern the recall of images from the subconscious. The ideas which emerge most frequently into our conscious minds are those around which our emotional interests are centred. This, they suggest, indicates that we might choose for experimental subjects persons who have common interests. Some of their results indicate that emotional attachments might play a part. It might be that under certain circumstances subjects could be used between whom there are blood linkages or strong personal attachments. An easy (and cheap) experiment would be to give some rats conditioned responses and to observe the behaviour of their siblings on the presentation of the stimulus. They would, of course, have to be carefully isolated but an advantage would be that ideas entering a rat's mind (if it has one) would be (presumably) comparatively few, and simple. Furthermore, this would permit a good scoring system to be used, the experiments would be easy to replicate and the animals would be left for other experiments.

The powers of extending and directing the conscious mind are discussed by Kenneth Walker in his book on mysticism, "The Conscious Mind", and Soal and Bateman refer to a similar process while discussing telepathic precognition. They remark that it may be that we are all in touch with future events in our own lives at the unconscious level, but that normally such foreknowledge never reaches our conscious minds. This, as they point out, would seem to imply that physical events are the realization of timeless mental patterns which are neither created nor destroyed.

It is generally accepted by psychologists that that there is no such thing as an instantaneous mental experience. Every act of perception, or of imagination, occupies a small but finite interval of time. We are not fully conscious of an event until it has faded a little into the past. So far as our mental experience goes, there is no sharp dividing line which separates the present from the past. Soal and Bateman describe how H. F. Saltmarsh[15] in 1934 suggested that this short interval of time, over which every act of awareness is spread, embraces not only a fragment of the past but also a little bit of the future. The actual extent of an individual's "specious present", as it is called, may vary with his state of mind. When he is alert, it will be shorter than when his attention is diffused. In other words, the more sharply conscious and awake he is, the briefer will be the act of perception. Therefore, according to this theory, it might be reasonable to suppose that, as one recedes from the fully conscious state to the deeper "subconscious" levels of the mind, there will be an increasing spread in what we experience as the "present moment", and this spread will embrace more of the future as well as more of the past. (Professor Wigner talks of a dividing line between the observer, whose consciousness is being affected, and the observed physical object which can be shifted towards the one or the other to a considerable degree but which cannot be eliminated). As there is very good reason to believe that extra-sensory cognition

takes place at sublimal levels of the mind, it is therefore, according to this theory, quite possible that a mental event which, for the conscious self, is either in the past or the future, may, for a subconscious level, be within the span of the present.

We can interpret these phenomena, together with the " higher " levels of consciousness of the mystics, roughly in terms of the " mountain-range " analogy of Jung's psychical world by equating them to a rolling belt of mist of varying thicknesses and at shifting depths below the peak. This could include Freud's " pre-conscious ", and E.S.P. would be analogous to the acoustic and visual tricks played by such mists, particularly when they enveloped a pass between two peaks.

Soal and Bateman accept that Saltmarsh's theory leaves unanswered how we become aware of an event which has not happened. Yet, they say, we should hesitate to suppose that an event in the future can influence or cause a present event (it must be remembered that they wrote about fifteen years ago). They ask: May it not be as Dr. Wassermann, of Durham University, suggests, that world events have pre-existing mental patterns, and that it is these patterns, and not the events themselves, which we contact in cases of precognition ? Themselves timeless, these patterns are in the process of realizing themselves in time. Perhaps as Wassermann suggests, the latent patterns of all possible events pre-exist—both those that will be realized and those that will never become actual. He thinks that an infinity of mental patterns is associated not only with particles of living matter, but with every fundamental particle in the universe. (His theory seems a remarkable fusion of the ideas of Fechner, Kofka and Cantor, with ones anticipated from Wheeler, Yukawa, de Broglie and others—and what a prediction of " quarks " !)

Soal and Bateman think highly of Wassermann's view of precognition saying that it does something to clarify the situation concerning precognition. There is no longer need to ask such questions as how can causation work backwards in time, or how can a future event influence a present event. Nor need we postulate extra dimensions of time for which we have no empirical evidence whatever. (We may note with interest that one such theory involving five dimensions requires a radius of curvature, along the fifth dimension, of 10^{-30} cm.)

Another theory which implies the existence of another time dimension, and which also provides an account of a possible mechanism for precognition, is that of the branching universe[16]. The " branching universe " branches out at each micro-micro-instant into countless myriads of universes having no communication with one another by any known method. Dr. Good, in " Speculations Concerning Precognition "[6], describes precognition in this system thus: " The psychological twist to the branching-universe theory is that you can, after all, get a glimpse into a future. But this is not a future of *all* the individuals into which you split at each moment. In other words: along a second time dimension countless futures exist *now*, but each will seem unique when it arrives along the ordinary time dimension . . . We all have innumerable identical twins with whom we very seldom communicate." In his article Good refers to an enthusiastic assessment of Everett's paper by John A. Wheeler. He also refers to the experiments of Soal and Bateman, Wasserman's field theories of the mind, Feynman's theory of positrons, and to another paper by Whately Carrington.

Although we cannot treat it fully here, a theory of R. B. Braithwaite,[17] contains concepts which at first sight appear rather surprising, but agree remarkably well with the foregoing. This theory offers a postulational definition of chance in which the key postulates state when to reject a statistical hypothesis. The criteria are empirical since the rejection tests cannot be used *in vacuo* but only on the basis of observed knowledge. A rejection, or any series of rejections, never " yields certainty " in the sense that all these rejections may be cancelled by a further test. Braithwaite points out that what John Dewey called the " quest for certainty " is, in the case of empirical knowledge, a snare and a delusion.

Braithwaite remarks that neither Fisher nor his disciples have expressed themselves as precisely as could be desired upon the logical relationship between the " hypothetical infinite population " and the random samples of it. He offers a model for probability theory (with undertones of Cantor and Wheeler) based on class-ratio arithmetic.

This theory has been very severely criticised by I. Hacking[18], who declares that many of his (Hacking's) ideas come from Fisher. The theory asserts that k-rules of rejection give the meaning

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Gestalt psychology, however, has actively criticised the associationist view of memory. It has called attention to the fact that contiguity of mental elements in time and space does not, of itself, guarantee their association and does not insure their mutual recall.

A sort of " mental energy " is needed to produce association and recall. Gestalt terminology would refer to a need or an interest. Associative binding by contiguity of elements would be just as ineffectual as the coupling of two railroad cars which were being shunted about and happened to touch each other. Recall of one element by another cannot occur without special mental energy any more than the railroad car can move without being attached to a locomotive.

of statistical hypotheses. But k-rules differ among themselves, according to the value of k. Hence different k-rules must attach different meanings to statistical hypotheses. Hacking writes "Better, each k-rule defines what I shall call k-statistical hypotheses; instead of using the term 'chance' we may speak of k-chances, namely the chances mentioned in k-statistical hypotheses, and whose meaning is given by k-rules of rejection."

Hacking then remarks that there is nothing intrinsically objectionable to a whole continuum of k-chances, where k may be any real number. He writes that his purpose is to explicate his idea of a physical property, long run frequency; perhaps to do this a continuum of possible explicata is necessary. This at any rate is Braithwaite's view of the matter. Then Hacking continues to show how, in his opinion, Braithwaite's theory is very odd. Hacking objects to k_1 and k_2-chances (as physical properties) of the same thing being different. He dismisses this as ridiculous, saying "no remotely plausible answer comes to mind". However, in view of Professor Wheeler's description of physical events as "some sort of resonance hybrid of any number of conceivable fluctuating geometries" and of space geometry as having a "probability amplitude for this, that and the other geometry, each differing from the other at the 10^{-33} cm scale of dimension", Braithwaite's conception does not seem so implausible.

Hacking states that it is absurd to imply that our private hopes and fears determine the meaning of chance. Unless this is based on a misunderstanding of Braithwaite's views (which is unlikely because Braithwaite proof-read for him), we have seen enough (it is hoped) to suggest that this is dogmatic.

At this point we might consider the remarks of Professor Gerald Feinberg[19] on distributions of matter, and of Dr. Joan Wynn Reeves[20] on separate realms of existence for entities. Professor Feinberg, talking of the future of physics, says: "Another problem I think physics will have to deal with is the interrelation of the universe in the large with the behaviour of objects in the laboratory. This problem is sometimes referred to as Mach's principle, because Mach raised the issue in connection with the inertial properties of matter. At first sight this problem would seem contrary to the history of physics since the time of Galileo. In our period physics has been fairly successful in accounting for laboratory phenomenon, while taking into account only the effects of nearby objects. Many physicists would regard any contrary assumption as a form of astrology. But Mach in the past century and Einstein in this one pointed out that the assumption that physical laws in a universe containing only a few objects would be the same as they are in our universe may lead to difficulties. For example, Einstein pointed out that if the earth were alone in the universe and Newton's laws were still valid, it would be possible for an observer on the earth to determine whether or not the earth was rotating by measuring the flattening of the poles. This conclusion seems counter intuitive, since one is inclined to ask: Rotating in relation to what? One possible way out of this problem is the one suggested by Einstein, who said that the inertial properties of matter arise when a body is accelerated relative to the average distribution of matter in the universe. According to this view, the inertial effects come from the gravitational force exerted on a body in the laboratory by the remaining bodies in the universe. This force depends, among other things, on the relative acceleration of two bodies. It also appears that the main contribution to the force on a given body comes from the distant background of galaxies. It is not yet clear whether or not the gravitational force of these galaxies is quantitatively sufficient to account for the inertia.

If this is indeed the correct explanation of inertia, a new problem arises. In order to know that the laws used to calculate the inertial effects are correct, we would have to know how all physical laws, including the law of gravitation, depend on the distribution of matter in the universe. That is, we would have to know the laws of physics for all conceivable distributions of matter, from an empty universe to one filled with matter in arbitrary motion. The orthodox view would be that the fundamental laws are independent of the distribution of matter. This leads to problems such as the one of the solitary rotating earth that I have cited. It may be possible to find the laws of motion for any distribution of matter, although to do so it will be necessary to assume that some laws do not change with the distribution. If this can be done, we might be in a position to understand some apparently accidental features of our world, such as the fact that space has three dimensions. However, the distribution of matter would still have to be prescribed arbitrarily. There is another possible approach to the connection between the distribution of matter and the laws of motion. This has been emphasized by Dennis Sciama in his brilliant book "The Unity of the Universe". According to Sciama, it may be that the connection between the laws of motion and the distribution of matter is so rigid that there is only one possible set of laws and one possible distribution of matter, those of the universe we inhabit. This is an extension of the view of Liebniz, who argued that, out of logical necessity, the universe could only be the way it actually is.

Similar views have been expressed in the context of particle physics by Geoffrey Chew and his " bootstrap " school (an alternative theory to that of quarks).

Clearly this approach also has its problems. In particular it seems easy to imagine logically consistent universes, very different from ours, such as a world with no bodies in it at all, or a world with particles permanently fixed. Perhaps, in order to rule out these worlds, it is necessary to supplement the requirement of logical consistency with the requirement that there be an observer to make measurements ".

It is interesting to note in Professor Feinberg's article a reference to the idea of different physical laws corresponding to differing distributions of matter being regarded as a form of astrology. This is not without interest because:—

(a) In C. S. Lewis's " Perelandran " trilogy the idea of individual spirits being " responsible " for particular planets is an integral part of the story

(b) Sir Charles Sherrington in " Man on his Nature " writes of the " planetary aim " and " planetary evolution

(c) Research is just beginning to uncover the effects of gravitational influences upon biological mechanisms (lunar observations have even been associated with psychological effects).

From the logical point of view Dr. Joan Wynn Reeves, in " Body and Mind in Western Thought" traces out the line of thought that moved at the turn of the nineteenth and twentieth centuries towards sensory realism and interest in logical relationships. She points out that in nineteenth-century interest in " fusion " and " integration " there lurked the logical possibility, not only of the kind of idealism argued by Bradley, but of the more sinister species of absolutism wherein the distinctions of human and other individual objects begins to get lost. According to this argument, based on a subject-predicate logic, there is in the long run only one entity of which all others are in some obscure sense qualities. She writes: " The distinctive contribution of writers in the best of the English empirical tradition, such as Moore, Whitehead and Russell, was to put their fingers on the doubtful logical assumption underlying this view. Associated with this, specially in Russell's thinking, was wider recognition of the different logical function of similar grammatical forms and of the kind of mistake that arises if this difference in function is forgotten. If we treat all descriptive phrases as if they pointed to entities, as do demonstrative pronouns, then, like Meining, we have to invent different realms of ' Being ' for housing unicorns and chimeras ". Dr. Wynn Reeves also remarks that it is possible historically to trace the fusion of relativity theory and this relational logic into Bridgman's " The Logic of Modern Physics", by which relational thinking and operational definition penetrated modern psychological thought. This section of her book she closes with the warning: "Again, one aspect of this view is on the side of freedom from absolutism, from over-identification, from metaphysical monsters, and on the side of this experience and this individual person being very distinct from that. But the danger of analysis is a defensive linguisticism which is self-defeating. It has been said, if men cannot live by bread alone, neither can they live on antiseptic, and whether mind-body problems could be solved or dismissed by logic and linguistics only remains, as I have indicated, a very open question. Even the new logic should be a tool, not a master ".

The question of the existence of other worlds and universes, then, is at least open to speculation. But as Professor Eugene P. Wigner points out in his article " Remarks on the Mind-Body Question "[6], the term " existence " is pretty meaningless with regard to consciousness. Professor Wigner, himself a physicist, goes on to say that until not many years ago, the " existence " of a mind or soul would have been passionately denied by most physical scientists and that there are several reasons for the return, on the part of most physical scientists, to the spirit of Descarte's " Cogito Ergo Sum " which recognises the thought, that is the mind, as primary. First, says Professor Wigner, the brilliant successes of mechanics not only faded into the past; they were also recognised as partial successes, relating to a narrow range of phenomena, all in the macroscopic domain. When the province of physical theory was extended to encompass microscopic phenomena, through the creation of quantum mechanics, the concept of consciousness came to the fore again; it was not possible to formulate the laws of quantum mechanics in a fully consistent way without reference to the consciousness. He quotes W. Heisenberg[21]: " The laws of nature which we formulate mathematically in quantum theory deal no longer with the particles themselves but with our knowledge of the elementary particles ". And also " the conception of objective reality . . . evaporated into the . . . mathematics that represent no longer the behaviour of elementary particles but rather to our knowledge of their behaviour ". Wigner then points out that all quantum mechanics purports to provide are probability connections between subsequent impressions of the consciousness and that the dividing line between the observer and the observed object, though it can be shifted, cannot be eliminated.

Professor Wigner then states two theses. The first thesis is that it is very likely that, if certain physico-chemical conditions are satisfied, a consciousness, that is the property of having sensations, arises. The sensations will be simple and undifferentiated if the physico-chemical substrate is simple; it will have the miraculous variety and colour, which the poets try to describe, if the substrate is as complex and well organised as a human body. The physico-chemical conditions and properties of the substrate not only create the consciousness, they also influence its sensations most profoundly. Professor Wigner asks: Does, conversely, the consciousness influence the physico-chemical conditions? In other words, does the human body deviate from the laws of physics, as gleaned from the study of inanimate nature? He retorts the traditional answer is "No"; the body influences the mind but the mind does not influence the body. Yet, he points out, at least two reasons can be given to support the opposite opinion: this is his second thesis. He then proceeds to show that the being with a consciousness must have a different role in quantum mechanics than the inanimate measuring device, and to observe that we do not know of any phenomena in which one object is influenced by another without exerting an influence thereupon (Sir Charles Sherrington made this point: Wigner's discussion subsequent to this on the absorption and emission of photons is reminiscent of Sherrington, Burt and Waddell). Wigner concludes that we may be able to discover phenomena postulated by the second thesis, in which the consciousness modifies the usual laws of physics. Such a phenomenon was described by Sherrington[22] when he wrote: "... We have to accept that finite mind is in extended space.

"The action should be reaction. In that case mind influences energy ... Reversible interaction between the 'I' and the body seems to me an inference validly drawn from evidence. How can a reaction in the brain condition a reaction in the mind? Yet what have we sense organs for, if not for that? This difficulty with sense is the same difficulty, from the converse side, as besets the problem of the mind as influencing our motor acts.

"I would submit that we have to accept the correlation and view it as interaction: Body $\leftrightarrows$ Mind. Macrocosm is a term with perhaps too medieval connotations for use here; replacing it by 'surround', then we get surround $\leftrightarrows$ body $\leftrightarrows$ mind. The sun's energy is part of the closed energy-cycle. What leverage can it have on a mind? Yet through my retina and brain it is able to act on my mind. The theoretically impossible happens. In fine, I assert that it does not act on my mind. Conversely my thinking 'self' thinks that it can bend my arm. Physics tells me that my arm cannot be bent without disturbing the sun. Physics tells me that unless my mind is energy it cannot disturb the sun. My mind then does not bend my arm. If it does, the theoretically impossible happens. Let me prefer to think the theoretically impossible does happen. Despite the theoretical I take it my mind *does* bend my arm, and that it disturbs the sun". In this section and the two preceding sections we have seen much to support this argument that mind *does* influence matter and, moreover, we have limited our field of reference to science and philosophy with no recourse to religion. We can perhaps bring Sherrington's equation up to date in view of what we have seen of modern views of E.S.P., particle physics, Gestalt and Analytical Psychology, particularly as Sherrington himself pointed out that no longer can a distinction be made between living and non-living matter, by suggesting that it be amended to Entity $\leftrightarrows$ Surround or, perhaps (following Wigner) to Consciousness $\leftrightarrows$ Surround.

We have already remarked on the pantheistic appearance impressed by phenomena in the fields mentioned in the preceding paragraph upon theories of the mind. Let us now consider the pantheistic (and monistic) flavour of some of Sherrington's arguments for Natural Theology. This is not particularly surprising for on his own admission his view of Natural Theology approaches the views of Aristotle: it might be argued that his view is lower down the "Deistic Scale" towards Pantheism than that, for example, of Hardy. In fact, his relation to Hardy seems similar to the relation between the pantheisms of Pope and of Wordsworth.

Sherrington tells us that man is a product of nature and that science concurs with this. We are asked "Between these two, perceiving mind and the perceived world, is there nothing in common? Together they make up the sum total for us; they are all we have. We called them disparate and incommensurable. Are they then absolutely apart? Can they in no wise be linked together? They have this in common—we have already recognised it—they are both of them parts of one mind. They are thus therefore distinguished, but not sundered. Nature in evolving us makes them two parts of the knowledge of one mind and that one mind our own. We are the tie between them. Perhaps we exist for that".

We can also compare the picture painted by Sherrington of conscious and unconscious mind with Jung's picture of mental life and with the substratum as it appears in particle physics; bearing in mind, in particular, previous references to the neutrino and Feinberg's reference to particles

as " ripples on an ocean " together with Ramm's description of the neutrino as forming " the sea around us " (see Footnote). Sherrington writes: "Aristotle wrote of ' unconscious purpose ', but here it would seem is unconscious inference . . . A mind which is not part of experience seems at work. To answer ' this is mental because the mind uses it ', is not quite enough. To call it the sub-conscious seems to declare better its nearness to mind.

" The transition from recognisable mind to unrecognisable seems gradual. The mind which we experience, if we try to extend our experience into the process of its making, seems to become almost at once unable to be experienced. It eludes us by becoming sub-conscious. It is as though our mind were a pool of which the movements on the surface only are what we experience. The mind which we experience, that is, which is our mutual experience seems to emerge from elements of mind which we do not experience ".

To sum up, we can do no better than to quote Professor Burt once more[24]. " The account which both physicists and physiologists commonly give of the process of perception seems to me to be psychologically misleading. They take the world of physics to be the real world, and the world of consciousness is assumed to be merely an appearance of this reality—an incomplete, fragmentary, and distorted selection of the grosser aspects of a self-existent physical universe. The ' sensory inputs ', originally received by our eyes, ears, skin, and muscles, have to be combined (so we are told) ' to give some kind of coherent synthesis '. And even so, the results only supply us with ' a kind of map or model . . . symbolic of events which they are quite unlike. And the *real* physical world has to be ' inferred from the symbolic data ' (Eccles, J. C.).

" This treats ' the conscious world of common-sense ' as primarily a world of sense-data, whereas it is from the very outset a world of things perceived. What the ' plain man '—and indeed the plain baby and the plain animal—are conscious of, are not simple sensations from which complex physical objects are inferred and constructed, and then projected into external space, but three-dimensional objects, stereoscopically perceived, out there in space from the start. Indeed, even when the quantum physicist himself undertakes an experiment to verify his theories, he still describes the apparatus and the results he observes in terms of this everyday perceptual world. Fact, as Heisenberg observes, is that which can be described in the language of common sense. The theories are inferred. Contrary therefore to the physiologist's description, it is the world of consciousness which, so far as our meagre knowledge can take us, brings us nearest to the ' real world ' ".

One of the latest theories[23] postulates the " ubiquitous " existence of small particles called " tamaids ". D. T. Lewis shows that the masses of the known, neutral subatomic particles can be calculated with considerable exactitude by assumptions of a linkage between agglomerates of tamaids and π mesons. He points out an interesting coincidence that a certain tamaid agglomeration could have almost exactly the hypothetical mass of the quark. The comments of the previous section concerning the applicability of the logistic function to the problems of the nucleus apply here also. (In fact, appropriately enough, these comments can be enhanced by the observation that the logistic has been shown capable of describing results of scattering experiments and experiments to determine " sea clutter " *i.e.* the effects on a radar screen of ripples and other peculiarities of the ocean surface).

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THE 7th INTERNATIONAL CONFERENCE ON MICROWAVE AND OPTICAL GENERATION AND AMPLIFICATION HAMBURG 16th-20th SEPTEMBER 1968

Reported by A. J. Monk, B.Sc., M.I.E.E., R.N.S.S.

This Conference was the seventh of a series held every two years in Europe, the previous ones having taken place at various locations in England, France and Holland. They are mainly concerned with the field of microwave generation and amplification, but also include papers on the field of quantum mechanics.

The Conference is internationally recognized as being the most important one in Europe covering the microwave devices field, and in consequence one finds there are contributions from America and Japan as well as most of the European countries. In fact the list of 378 people who registered to attend the Conference included 16 nationalities. As was to be expected, the largest contingent of about 150 people came from various laboratories in Germany, but it is interesting to note that both France and England were represented by about 50 participants, and that there were 35 visitors from America. There were, in addition, about 15 people from Russia and the other countries of the Communist Bloc.

The Conference was run in three parallel sessions which created some difficulties and a certain amount of to-ing and fro-ing between various lecture halls. However, the organisers had arranged the programme so that as far as possible papers on similar subjects were not delivered simultaneously in different lecture halls.

In addition to the four introductory survey papers, there were 125 others which were divided under the following headings:—

1. *Linear Beam Devices.* (klystrons, TWTs etc.) There were 37 papers concerned with these.

2. *Solid State Devices.* Of the 45 papers delivered on this subject, 16 were concerned with transferred electron devices (Gunn and LSA oscillators and amplifiers), four were about avalanche devices (*IMPATT* oscillators), and the remainder (25) were concerned with microwave transistors, parametric amplifiers, tunnel diodes and other solid state applications at microwave frequencies.

3. *Quantum Electronic Devices.* The 24 papers classified under this heading were principally concerned with lasers, masers and non-linear optics.

4. *Crossed Field Devices.* That there were only 11 papers on this subject probably reflects the fact that there are now grave doubts as to whether crossed field amplifiers will be able to meet the sophisticated requirements of new radar systems.

5. *Noise and Gaseous Plasma Devices.* There were only eight papers concerned with this subject, and this is probably once again due to

the fact that there are grave doubts as to whether satisfactory practical plasma devices are likely to emerge in the near future.

Microwave valves are now very well understood, and most of the work reported on this subject was concerned with minor technological improvements and slightly more sophisticated theories for explaining the behaviour of beams and structures. There were, in addition, a number of papers describing fully developed valves which had a superior performance to similar devices reported in previous years.

The Gunn oscillator has, of course, been recognized for some time as one of the most promising devices to replace the vacuum tube as a microwave generator in future radar systems. It was, however, apparent from the papers presented at the Conference that the avalanche device probably now holds even greater promise because of its higher power capabilities and greater efficiency. For both these devices the most significant advance in the past two years has been the improvement in understanding, and this has resulted in a greater appreciation of the types of circuit and techniques which must be employed in order to obtain the best performance. For example, it would appear that three different classes of operation for transferred electron devices have been identified. They are:—

1. The transit time or Gunn mode.
2. The parametric or multiple dipole type of mode.
3. The low frequency negative conductance or *LSA* mode.

In the case of the avalanche diode, there were two most interesting papers presented by the staff from Cornell University, which gave a convincing explanation of the part played by the various resonances in enabling one to obtain very much higher efficiencies. Theoretical figures of up to 55% have been predicted, and 20% at 3·2GHz has been obtained. By the use of diamond as a substrate, CW powers of up to 100 watts at X-band should be obtainable.

The lectures on quantum electronic devices were not very well attended, probably because this particular Conference came just after the Quantum Electronics Conference in the U.S.A., and the latter was obviously preferred by potential speakers. Most of the papers were concerned with parametric effects using the non-linear optical properties of various materials. The conversion efficiencies and gains were, however, extremely low, and it is difficult at present to see any significant application for the experimental systems described at this conference. Workers at Bell Telephone Laboratories have, however, at other conferences described frequency doubling from a Neodymium YAG laser as a practical way of producing green light at a reasonable conversion efficiency.

Summarizing, it would appear that the emphasis in the Conference is changing so that most of the scientifically interesting work reported is being done in the solid state field. The vacuum tube papers being primarily concerned with improvements in technology. It is likely that at any future Conferences in this series the balance will swing even further so that the majority of the papers will be concerned with solid state microwave devices. However, the emphasis in the solid state field is somewhat different from that of most Conferences covering this subject, since the majority of authors appear to be less concerned with the basic physics and concentrate their attention more on the user aspects and in particular the external circuit requirements.

It will, therefore, continue to be a useful Conference, though it could probably with benefit drop the field of quantum electronics, which is not of significant interest to the majority of people who attend.

It is expected that the papers presented at the Conference will be available in bound form within three months. Any *J.R.N.S.S.* readers who would like a more detailed report on the proceedings than that given here should contact DCVD, Old Admiralty Building, Whitehall (Telephone Extension 1303).

PHYSICS EXHIBITION 1969

The Navy Department's Research and Development Establishments again exhibited at the Physics Exhibition, held this year at Alexandra Palace, London, on 10 - 13th March. Five establishments participated, each with exhibits which aroused considerable interest amongst the large number of visitors to the exhibition during the four days it was open.

Illustrations of the stands are shown elsewhere in this issue and very brief technical descriptions are given below.

ADMIRALTY ENGINEERING LABORATORY

A fluidic digital r.p.m. counter. This fluidic digital r.p.m. counter is being developed for measuring the revolutions of a ship's propeller shaft where the environment can be unfavourable to the efficient operation of more conventional methods. The fluidic circuit, incorporating standard fluidic components operating on clean, dry, low pressure air, was designed for counting over the speed range 0 to 250 r.p.m. and to provide a digital display updated every five seconds.

It is considered that the system would be easy to install and maintain and could also be developed to have a high degree of reliability, the aim being to have an accuracy of $\frac{1}{2}\%$ of maximum speed and to be operative in ambient temperatures of 15°C to 75°C.

Using a 12 hole disc on the shaft, the counter receives a maximum of 50 pulses per second from the back pressure sensing tube. The binary counter unit which consists of 10 binary counter elements assembled to form a binary-decade counter, counts the train of pulses from the sensor over a period of five seconds after which the hold unit stops the pulses entering the binary counters and the total is held by the control circuit whilst it is transferred to the memory. The counter and timer are then returned to zero and the process repeated whilst the data, having been transferred to the memory, are displayed. By using a pulse to transfer the total from the counter to the memory at the appropriate time, the decoding and display unit may be coupled directly to the memory and it thus requires no separate signal to command a new display.

ADMIRALTY RESEARCH LABORATORY

Speech communication in oxy-helium at depth. Divers working on the sea bed need to communicate between themselves and the surface. Direct speech communication becomes increasingly difficult with increasing depth due to the distorting effects of the oxy-helium breathing mixture, ambient pressure and acoustic feedback.

The intelligibility of the divers' speech can be improved by processing the received signal. One method is to operate on the speech in the time domain, using a scanning system. Another method is to operate in the frequency domain, using a vocoder technique. The Joint Speech Research Unit at Eastcote and the Admiralty Research Laboratory at Teddington are comparing these two approaches mainly by means of computer simulations to determine a satisfactory solution.

ADMIRALTY SURFACE WEAPONS ESTABLISHMENT

A microwave integrated-circuit radar beacon. Radar beacons are being developed for navigational purposes on buoys, lightships and lighthouses. The latest design and the one exhibited is being developed at Admiralty Surface Weapons Establishment using microwave integrated circuit techniques. All the microwave components are printed on a single substrate of alumina 4 in. square. The thick film video receiver, pulse standardizer, varactor sweep generator and Gunn oscillator switching circuits are also incorporated on the same substrate.

The beacon transmitter is a pulsed Gunn oscillator in a microstrip resonator which is varactor tuned over the marine radar band. The oscillator is coupled to a four slot array microstrip aerial by a ferrite circulator, the third arm of which is coupled to the microwave detector. In operation the beacon transmits a long identifying pulse on receipt of an interrogating pulse from a ship's radar. The long pulse marking the position of the buoy is displayed on the ship's radar.

The object of the use of these techniques is the improvement of reliability of this type of equipment. Further advantages to be obtained with this type of construction are a lower cost and a considerable reduction in size.

Specification:

Aerial:	omnidirectional
Transmitter:	peak power 100 mw pulse length 18μ swept frequency band 9·3 to 9·5 GHz
Receiver:	accept pulses 40 to 1·2 μs pulse repetition frequency 1 kHz detector sensitivity −50 dBm for 1 MHz bandwidth

Also shown by A.S.W.E. at the exhibition was a working model of the *Shipborne Tripod Level Platform.* Basically, this piece of equipment virtually eliminates roll, pitch and yaw, creating a stable platform on which radar aerials etc. may be mounted.

ADMIRALTY MATERIALS LABORATORY

Magneprint and magnestamp—new methods of magnetic crack detection. An entirely new technique for the production of permanent records of magnetic crack detention is exhibited. A strippable magnetic sensing paint is applied to the surface of the work, which is then magnetized. The stripped paint film is developed in the normal magnetic ink and produces an image of the defects, together with topographical details.

Variations of this technique were shown, together with a special system using the basic principle in a compact device which enables a very rapid visual impression of defects to be obtained, which can then be "rubber-stamped" on to a report pack for record purposes in design.

Amlec eddy current crack detector. A new method of eddy current crack detection, with very simple and effective lift-off compensation for ferromagnetic materials, was exhibited in 1967. This has now been developed and the two commercially available instruments were shown, together with some special versions designed for use by British Rail for the detection of defects in rails.

SERVICES ELECTRONICS RESEARCH LABORATORY

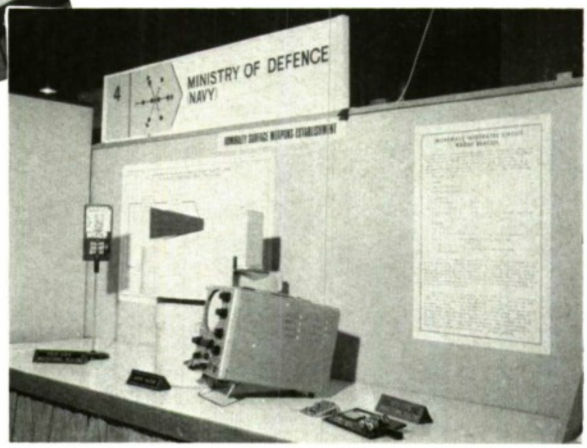
Electroluminescence in gallium phosphide. Gallium phosphide is a III-V semiconductor with an energy gap of 2·25 ev, which is large enough to permit the emission of light by the re-combination of electrons and holes. Forward-biased gallium phosphide diodes may therefore operate as solid state lamps. Both red and green lamps have been produced. The red lamp, in which the radiative recombination mechanism involves nearest neighbour pairs of zinc and oxygen impurities, is at a fairly advanced state of development, and efficiencies of the order of 1% have been reported. At SERL, work has reached a stage where red emitting diodes with efficiences greater than 0·5% can be reliably produced, and device development based on these diodes is in progress.

Such lamps have many practical applications, their main advantages being robustness, reliability, compact size, and low voltage drive requirements, compatible with solid state circuitry. The lamps may be used singly, as indicator lamps, or built up into arrays for alpho-numeric displays, film marking or other applications calling for a low resolution visual display.

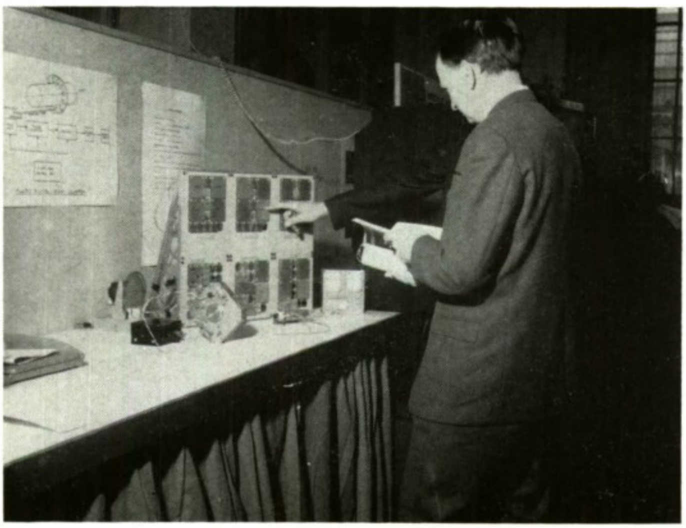
A major obstacle to the development of these devices has been the difficulty of producing large gallium phosphide crystals, of the required purity and perfection, which arises out of the high dissociation pressure of this compound at its melting point. This obstacle has recently been overcome at SERL by the application of the liquid encapsulated Czochralski technique to gallium phosphide, and crystals of up to 60 g weight and of controlled doping level have been grown. Slices from these crystals are used as substrates on which large area p-n junctions are formed by epitaxial deposition of doped gallium phosphide from gallium solution. The growth of gallium phosphide single crystals and the fabrication of electro-luminescent diodes were described in the first section of the exhibit.

The second section was concerned with fundamental research into luminescence mechanisms in gallium phosphide, and with the evaluation of electroluminescent diodes. The experimental techniques employed include cathodoluminescence and scanning electron microscopy. The third section of the exhibit gave a demonstration of prototype gallium phosphide diode arrays, used as alphanumeric displays.

Admiralty Research Laboratory
Speech Communication in
Oxy Helium at Depth

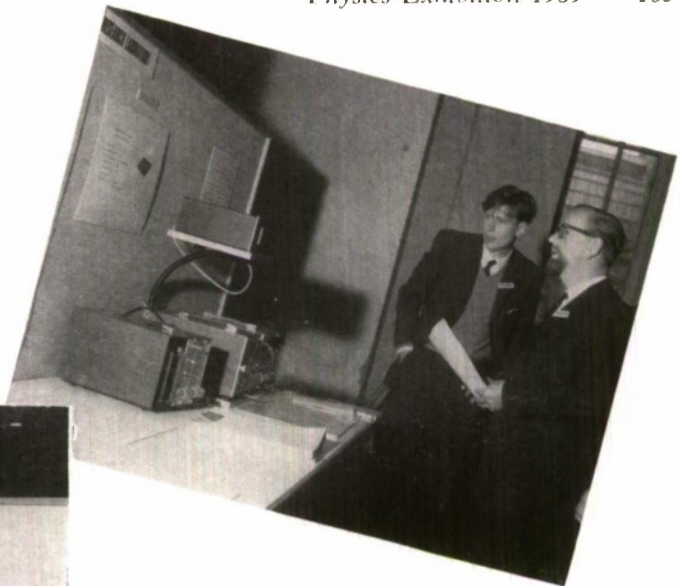


Admiralty Surface Weapons Establishment
Solid State Navigational
Beacon

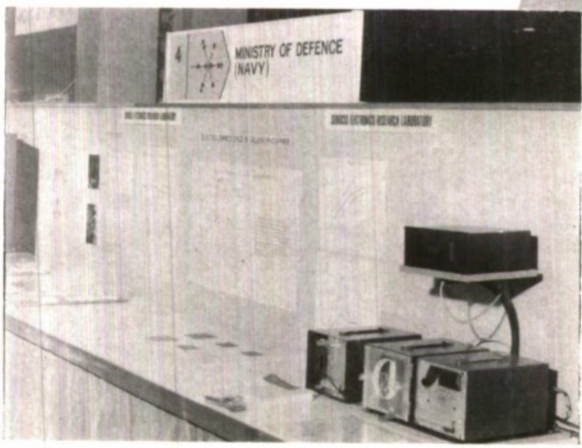


Admiralty Engineering Laboratory
Fluidic Digital R.P.M. Counter

Navy Department Exhibits

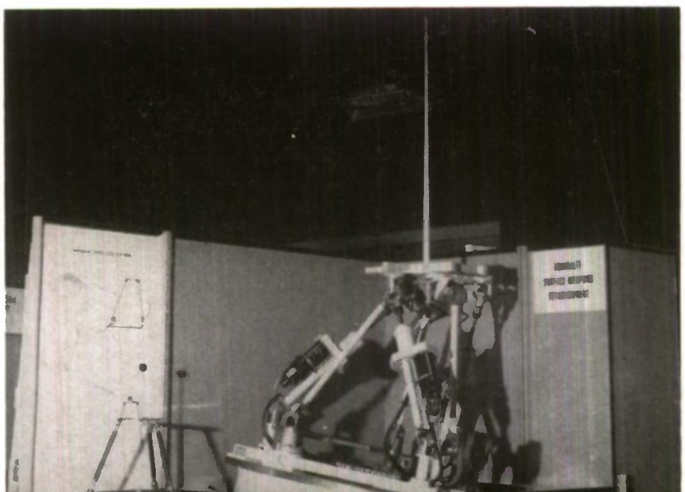


Admiralty Research Laboratory
Speech Communication
in Oxy-Helium at Depth



Services Electronics Research Laboratory
Electroluminescence in
Gallium Phosphide

Physics Exhibition 1969



Admiralty Surface Weapons Establishment
Shipborne Tripod Level Platform

OCEANOLOGY 1969

Undersea Equipment on Show at International Exhibition

The world's first international exhibition and conference on the subject of oceanology—the exploration and exploitation of undersea resources—took place at the Exhibition Centre, Brighton, between February 17th and 21st.

Entitled Oceanology '69, the exhibition attracted some nine national exhibits as well as a host of individual displays by specialized marine survey and engineering companies, papers from at least 15 nations were heard at the adjoining conference and symposium. It was the result of three years of planning on the part of the Society for Underwater Technology and B.P.S. exhibitions to bring together representatives of government establishments, industries and research interested in man's exploitation of the sea. Whilst the event had received some advance criticism as being too ambitious in scope to be justified by the present 'state of the art', Mr. Wedgewood Benn preferred to think that the Exhibition was well placed in time, coming shortly before the U.N. International Decade of Ocean Exploration, and when the importance of undersea exploration was at last becoming fully recognised. The exhibition itself certainly revealed the great extent of effort now being invested in the development of underwater equipment.

The exhibition took up three floors of the New Hall, and one of them was dominated by the United States section, organised under the auspices of the U.S. Government. On display were many sophisticated commercial products together with designs for major engineering projects for the future. The French and Italian exhibits demonstrated their respective national flair for diving technology. However, the biggest surprise, for the other exhibitors at least, was the strong showing of Japanese firms in ocean instrumentation.

Apart from the 'dry' exhibition, research vessels from several countries were open to visitors in nearby harbours. At anchor at Shoreham were the *Jan Polansky* from Poland, the Russian Arctic research vessel *Perseus III* and the British University Ship, *John Murray*. Also on show was a widewall hovercraft and a U.S. Navy one man submarine *Pegasus*.

Amongst other distinguished visitors to the exhibition were Mr. Short, Secretary of State for Education and Science, who opened the conference, and Lord Mountbatten.

Automatic Navigation

The increased accuracy now required of navigational equipment for hydrographic work and for docking of large vessels is well met by many of the systems displayed. Satellite navigation systems which allow position fixing to within a hundred feet or so were shown by D.E.C. and Magnavox. A doppler sonar system from the Marquarot Corporation measures drift relative to the bottom to within a quoted 0·5 per cent, and also the speed of swing of a turning ship.

As navigational aids and ship-borne data gathering equipment become more complex, the natural progression is towards automatic logging systems. The introduction to the market of robust microminiaturized computers now makes this a practical and fairly inexpensive proposition. Amongst the firms offering complete digital systems, with information displays in several parts of the ship are Ferranti Ltd., Elliott Automation, Decca, and D.E.C. of America. In all cases the computer itself is sufficiently small to fit into a standard rack mounting.

Some firms such as Hunting Surveys Ltd., Wimpey and Decca, provide a complete service

in hydrography and surveying. They have several professional teams on call and complete with the necessary equipment to meet a customer's requirements at short notice. Mapping and cartography, aerial photography and marine and land surveys are within their scope. This service is invaluable in cases where the quantity of work to be done does not justify the purchase of capital equipment.

Sub-oceanology

The vision of man living and working underwater for extended periods is no longer the preserve of science fiction. With the development of seabed habitats and submersibles it is already possible to provide a diver with an underwater 'dry' base from which he can make periodic surveys of the surrounding sea floor. However, the extent to which he can exploit these facilities, and perform useful work in the water still depends on his diving gear. Underwater swimming suits and tools were included amongst the exhibits of several firms, and it was clear that the emphasis in design is strongly placed on comfort and light weight. Siebe Gorman exhibited a suit moulded in neopren with heat sealed seams for increased flexibility. By partial inflation, the painful effects of high ambient pressure can be greatly reduced. The helmet is glass fibre and the breathing apparatus, specially designed for use from submersible work chambers, is a high pressure self-contained unit enclosed in a glass reinforced plastic case. On a neighbouring stand La Spirotechnique of France presented a wide range of diving suits, underwater cameras and communication systems designed by Cdr. J. Y. Cousteau.

Also exhibited by Siebe Gorman were two divers' re-compression chambers, one of which is being built for the U.S. Navy.

One of the discomforts experienced by deep sea divers breathing an oxyhelium mixture is the distortion of speech commonly known as the "Donald Duck effect". In the American exhibition one of the stands attracting a good deal of interest was that of I.E.C. featuring their divers' speech "unscrambler". Donald Duck when processed by this device was certainly more intelligible but still tended to sound rather like a "Diddyman".

Artists' impressions of existing or proposed seabed habitats abounded. The "Sea-Lab" and U.S. Navy Tektite are already well known, but it was encouraging to see the extent to which British industry is also participating in the field. The centre of the British Aircraft Corporation exhibit was a description of the Bacchus commercial habitat, suitable for up to six men diving for long periods at saturation diving depths.

In sharp contrast to the multi-million dollar projects of big industry is the interesting experiment being undertaken jointly by Imperial College and Enfield College of Technology, on a proverbial shoe-string budget. A cheap, easy to handle underwater habitat, suitable for two divers for 24 hours at a time, has been constructed. It will be fully tested in the Mediterranean during the summer. The construction is absurdly simple, being essentially a reinforced rubber bag attached to a tubular steel frame. Yet it works. The enthusiastic designers argue that there is a need for a simple habitat such as this which is economic in use and can be installed and removed from a working area with relative ease. Because these habitats could be put into operation in a short time, they may yield information on underwater living long before some of their giant cousins are off the drawing board.

Process in developing underwater television systems was the theme of Ball Bros. of Colorado, who were exhibiting their cableless underwater television link CUTlink. The system operates virtually in real time—a 200 line picture requiring one minute of scan. The picture data is converted to narrow-band acoustic signals and is transmitted to a hydrophone receiver below the ship. Obvious applications of the system are for search, rescue and salvage operations and also plant and animal life research.

Super Oceanology

Off shore drilling rigs become more and more elaborate. A new French adjustable tension anchoring system promises increased resistance to tilting of drilling platforms by currents, wind and swell. It is hoped to adjust these tensioning devices by computer control for optimum centering of the drill.

In future gas and oil from these rigs may be stored in floating containers and tanks shaped like inverted funnels, moored close to the platforms. Tankers will then load at sea, and the expense of laying pipelines ashore, and of dredging and providing harbour facilities for the modern mammoth tankers will be avoided.

Reliable and permanent anchoring in regions of unsuitable bottom material may be more successful using the Magnavox Self-Embedment Anchor. This is fired into the sea bed by release of hydrostatic pressure. The manufacturers consider this is particularly useful for marker buoys and for emergency anchoring during rescue work.

Ocean Systems, New York, have developed a special sealift crane for raising and lowering equipment from a ship into the sea. Features include a highly manoeuvrable arm, compensation for ship motion, and fast recovery speed to lift objects

quickly away from the effects of waves.

The wreck of the *Torrey Canyon* highlighted the difficulty with which very large vessels reduce speed and stop. However, the National Physical Laboratory believes that stopping distances may be reduced by about 35%, using a system of ducts. Water is directed from regions of high pressure to regions of low pressure and its backward momentum and some of the ship's forward momentum are destroyed in the process. The device is entirely passive and is brought into action simply by opening a valve.

Inspection of underwater pipelines, geological sampling for oil prospecting and many other operations on the sea bed will be much easier when Cammell Laird have constructed their newly designed sea bed crawler. This tank-like 50 ton device will be floated to the working site, where it will lower its wheels and flood its ballast tanks until it is able to pull itself down to the bottom by winch, while attached to an anchor. Once the vehicle is on the bottom it will " weigh " only four tons and be capable of moving and working over large areas of rough terrain in depths to 200 metres. Pressure chambers for transferring divers will be included, and fully equipped quarters will be provided for all the crew. This work will be handled by a joint company set up by Cammell Laird and N.R.D.C.

The N.R.D.C. also has an interest in several other projects including the manufacture of long rubber sausage like containers by Dunlop for transport of liquids in bulk at sea, and it is collaborating with Decca in a study of underwater navigation systems.

Remote Sensing

Several companies exhibited buoys designed to collect and transmit the information about meteorological and oceanographic conditions needed for weather forecasting. Other uses include measurements for the prediction of sonar performance. The larger buoys may become permanently manned mid-ocean stations for aircraft and shipping navigation. Information may be transmitted directly to receivers ashore, or where this is not possible, recorded and transmitted to satellites for re-transmission to land stations during a later part of the orbit. At present the high cost of large stations means that very few have been constructed.

One disadvantage of the surface buoy is its exposure to wind and waves. However, several companies exhibited buoys designed to submerge to depths of several hundred feet. These buoys, when firmly anchored, provide a very stable platform for temperature and current measurements free of errors intoduced by motions of the buoy itself.

For even deeper observations self contained ' pop-up ' instrumented capsules have been developed, using hollow glass or metal spheres. Once observations are completed ballast is jettisoned by acoustic command or by a time release mechanism, and the capsule rises to the surface. There it is located by radio or sonar transmissions, by flashing lights, or by the proverbial keen eye of the seaman.

Equipment for the scientific measurement of currents, temperature, salinity and sound velocity was displayed by several countries, and particularly by the United States exhibitors. Plessey, the largest British exhibitor, presented an extensive range including the Sippican expendable bathythermograph which has now been adopted for use by the Navy. The temperature measuring head, which falls at a steady rate, is connected to the recorder by a very fine conducting wire which eventually breaks. One version of this instrument is designed for use from a helicopter.

Notes and News

Admiralty Experiment Works

Over the past year an extension to A.E.W. in the form of A.E.W.I.I., a small laboratory on the Outer Arm at Gibraltar Dockyard, has been developed to aid on-site instrumentation during special sea trials held in the area. The facilities of the Anglo-U.S. A.U.T.E.C. Range in the Bahamas were also used for certain trials at the beginning of last year. An increasing volume of contract work is being undertaken both for national and international concerns. The first planar motion mechanism (P.M.M.) in this country was installed at A.E.W. in July of last year. In order to extend interest and knowledge in the use of this equipment for ship model testing, a three-day course and discussion is to be held, in association with the Department of Mechanical Engineering, University College, London, at A.E.W. to start at 1000 on Monday, 21st April 1969. Members from other countries already having experience in the P.M.M. are expected to attend as well as people with little or no experience. Recent visitors to A.E.W. have included the British Towing Tank Panel; representatives from Trinity House, Hawker Siddeley Dynamics; Naval Research and Development Center (Washington, D.C.), Esso Research (Texas); the Swedish State Shipbuilding Tank, Skipsmodelltanken (Norway); and Professor S. Motora with Mr. T. Inui from Tokyo University. In October we received a visit from the Director General Ships, Vice Admiral R. G. Raper. Mr. J. E. Conolly transferred from Bath to take up the new S.P.S.O. post of Chief Scientist at A.E.W. in the summer, and in the autumn, A.E.W. was joined by two new scientific grades: Mr. M. S. Chislett who had previously been at the Hydro- and Aero-Dynamics Laboratory in Denmark and the Naval Ship Research and Development Center in the U.S.A.; and Miss J. A. Harrington from East Anglia University. Mr. S. G. Lankester, after more than twenty years as Senior Scientist has transferred to the D.N.R.D.A. in London. Also Mr. F. P. Verdon of our computer section has transferred to the Computer Board for Universities and Research Councils in London.

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Admiralty Materials Laboratory

Dr. T. C. J. Ovenston attended the 1968 meeting of Sub-Group P, T.T.C.P., in Melbourne, Australia, in November and visited various Australian industrial and defence centres in order to assess the scope of support given to defence in the field of materials science.

Mr. G. N. S. Farrand visited Washington, D.C., during November, 1968, as a member of the North American Joint Selection Board.

Dr. K. H. Wheatley, P.S.O., rejoined A.M.L. on 9th December, 1968, after eleven months at R.N. College, Greenwich, where he passed the Naval Staff Course. He transferred to the Directorate of Scientific and Technical Intelligence on 6th January, 1969.

Mr. J. J. Elphick attended the 17th Research Conference on the Prevention of Microbiological Deterioration held at the U.S. Army Natick Laboratories, Mass., in November, 1968.

Mr. W. A. Smith, S.E.O., transferred to the Admiralty Engineering Laboratory (Electrical) on 4th November after 20 years' service at A.M.L.

Exhibits of silicon nitride ceramic work and of defect evaluation research were provided by A.M.L. at the Engineering Materials and Design Exhibition held at Olympia 2nd - 6th December, 1968. At this exhibition on 3rd December, Mr. D. Birchon gave a lecture entitled "What have Modern Metals to Offer to the Designer ?". Mr. Birchon also gave a lecture on "The Philosophy of Non Destructive Testing" at the R.N. Engineering College, Manadon, on 21st November.

A paper entitled "Some Approaches to the Use of Brittle Ceramic Material in Engineering Applications" was presented by D. J. Godfrey and P. G. Taylor at a one day meeting of the Institution of Mechanical Engineers on 3rd December, 1968.

A paper entitled "Activation-Controlled Delayed Fluorescence" by C. A. Parker and Thelma A. Joyce was published in Chemical Communications (1968, No. 22) 1421.

Mr. P. M. Wingfield and Mr. D. R. H. Jolly gave a talk to the Poole and District Technical Group on 29th October, 1968, on "Amateur Radio" which included a demonstration, during which amateurs in various parts of the world were contacted.

The "Open Days" at A.M.L. last October are continuing to arouse considerable interest in the work of the Establishment and enquiries for further information in the various fields exhibited are still being received. In addition, many favourable comments are being made on the very high standard of presentation. This is perhaps not so surprising when it is realized that so much time and enthusiasm was given by the Workshops, Drawing Office and Photographic Staff of A.M.L. in collaboration with the Navy's own illustrators.

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Admiralty Underwater Weapons Establishment

New Torpedo Testing Facility

A part of a new facility to be installed at A.U.W.E. for testing torpedo launching equipment is a pressure vessel 19 ft. dia. 40 ft. long, and weighing 105 tons. This was manufactured at the works of George Clark and N.E. Marine Ltd., Wallsend-on-Tyne, and the story of its journey between there and the laboratory where it is installed at A.U.W.E. is not without interest. The tank was lowered into the water by crane at the maker's works and towed by one of United Towing's tugs from there to Portland harbour where it was berthed at a buoy. It was brought ashore at a concrete ramp left from pre-invasion days, and from there on its transport became the responsibility of Pickfords. This was accomplished by the aid of a low-loader and three Scammels, each developing 380 h.p. Those familiar with Portland will realise that it was a somewhat hazardous journey through the narrow street of Fortuneswell, up the hill and round the sharp bends, especially in view

of the weather conditions since the time was immediately following the snow blizzard in February. The clearance in Fortuneswell was so small that it was necessary to remove (and replace) a projecting low window of a house. The journey was without incident, however, and the tank was on its final site in A.U.W.E. four hours after leaving the ramp. The illustration shows the tank passing the front of A.U.W.E.

The Imperial Service Medal awarded to Mr. Frank Voller was presented to him, on behalf of the Queen, by the Director, Dr. Benjamin, on January 31st, 1969. Mr. Voller is a leading Draughtsman who has been in Admiralty employment for 44 years, first at Portsmouth Dockyard, then in Mine Design at H.M.S. *Vernon*

and Havant, and finally at A.U.W.E. Since 1953, Mr. Voller has been concerned with works and buildings and has been an invaluable contact with the Ministry of Public Buildings and Works in all matters from the alteration of an office to the layout of a new building.

In returning thanks at the presentation, Frank astonished his colleagues by producing the medals presented to his father and grandfather who were also employed at Portsmouth Dockyard.

Presentation of Prizes and Indentures to Apprentices

The annual presentation of prizes to craft apprentices took place on Friday, December 20th, when Dr. Benjamin presented the following prizes

Principal Officers' Mess Prize Best Overall Apprentice 1st Year—T. Broad

Artificers Prize Best Craft Apprentice 1st Year—A. Pearce.

R.N.S.S. Prize Best Craft Apprentice 2nd Year—R. Jackson

R.N.S.S. Prize Best Craft Apprentice 4th Year—I. Wilkinson

R.N.S.S. Prize Best Craft Apprentice 4th Year—W. Spalding

R.N.S.S. Prize Best Craft Apprentice 5th Year—J. Collins.

Artificers Prize. The Most Marked Craft Advancement—A. Henderson.

Principal Officers' Mess Prize Best Overall Apprentice (Mechanical)—F. Tough.

Principal Officers' Mess Prize Best Overall Apprentice (Electronics)—A. Palmer.

Apprentice Training Committee Prize Best O.N.C. Results by Apprentice—J. Collins.

Apprentice Training Committee Prize Best O.N.C. Results by Scientific Assistant—R. N. Lees, T. C. Kearey.

The occasion was also taken to present indentures to the following Apprentices who had completed their training:

K. J. Peckover	N. S. Hirst	F. J. Tough
C. J. Russell	S. A. Clarkson	P. Holt
A. J. House	C. Bilke	R. Burt
R. Brown	R. W. Cattle	A. J. Nailer
A. H. Palmer	R. R. Halcrow	C. G. McFarlane
W. J. Spalding	R. E. Bowley	
N. A. Smith	B. Martin	

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Services Electronics Research Establishment

Mr. J. W. Allen has been granted four years special unpaid leave to take up a Research Fellowship at the University of St. Andrews.

Mr. M. S. Wills transferred to the Ministry of Defence H.Q. on November 8th, 1968.

Messrs. P. D. Lomer and M. Hillier visited the Philips Research Laboratories, Eindhoven, in November 1968 to see and discuss the Philips work on sealed-off carbon dioxide lasers and sealed-off neutron generators.

Mr. J. Pollard attended an exhibition and symposium on "Vacuum Instrumentation", organized by the Vacuum Group of the I.P.P.S. at Liverpool University on December 18th, 1968. Mr. Pollard acted as Chairman for one of the sessions.

Mr. M. J. Beesley attended a symposium on "Factors Limiting Photographic Performance" at the I.E.E., London in December 1968.

Mr. J. C. Vokes presented a paper on "Parametric Amplifiers" at the I.E.E. on November 11th 1968.

Mr. L. Large gave a lecture on "Ion Implantation" to the Electronics Group of the I.P.P.S. on January 14th 1969.

About seventy members of the Electronics Group of the I.P.P.S. visited S.E.R.L. on December 4th 1968, and a large part of the work of the laboratory was described and demonstrated. The visit was organized by Mr. L. Large.

A seminar on "Avalanche Diode Microwave Generators" was held at S.E.R.L. on 5th December 1968. This was sponsored by C.V.D. and was attended by over forty workers in this field from industry, universities and government laboratories. These devices have potential applications to radar and communication where reliable, compact and high efficiency microwave sources are required.

Retirement

J. W. La French NORMAN

James William La French Norman, Superintendent at the newly styled Admiralty Research Laboratory Extension, Glen Fruin, retired on 31st January, 1969, after thirty-one years' Admiralty service.

Born in 1907 in Norwich, Mr. Norman received his technical education at the Hackney Polytechnic and in 1923 joined the Cosmos Lamp Works at Brimsdown, a subsidiary of Metropolitan Vickers. Here he spent 14 years developing glassworking and high vacuum automatic machinery for the manufacture of lamps and radio valves. In 1937 he was appointed a Technical Officer at the Admiralty Research Laboratory, Teddington, where he joined the newly formed Acoustics Group concerned with the reduction of air and water borne noise from submarines. Mr. Norman was very successful during the war in reducing the noise from X Craft and by the design of combined shock and sound isolating mountings made a useful contribution to the reduction of structure borne noise from submarines, and which is still in use to this day. He was also prominent in the small team which set up the Noise Range, now A.R.L. Extension, Loch Goil. After the war Mr. Norman became Leader of the Acoustics Group for a few years and was promoted Principal Scientific Officer and during this period initiated basic studies into the mechanism of cavitation noise, and designed the first shock/acoustic mountings for a submarine main engine, and for heavy auxiliary machinery in surface ships. In 1950

Mr. Norman was appointed Superintendent of the newly merged Coulport and Glen Fruin stations forming the Admiralty Hydro-Ballistic Research Establishment, with the task of welding them into an effective unit and of making some headway in the admittedly difficult field of Water Entry Studies. Under his direction a multi accelerometer system was developed for the investigation of the whip and deceleration of full scale weapon models at water entry, and a store of useful information was built up before the Admiralty decided on financial grounds to reduce the Coulport station to Care and Maintenance in 1956. Mr. Norman was then able to concentrate all his energies on the re-equipment of the Glen Fruin Establishment, the development of sophisticated launchers and instrumentation for use at large model scales, and to undertake, in collaboration with A.R.L. a major study of whip effects and the correction of scaling errors due to atmospheric pressure. Under his management the facilities of Glen Fruin also became an important factor in the development of methods of underwater escape from ditched aircraft. About four years ago it was decided to re-activate the Coulport station and to replace the old full scale launcher with a new unit more suitable for modern requirements and capable of reaching out into deeper water. Mr. Norman has undertaken this new development in addition to his responsibilities at Glen Fruin. He is also continuing to watch over this major piece of work in a consultative capacity after his retirement until working up and acceptance tests have been completed. After that he hopes to move to a slightly warmer clime in the south-west of England to continue his painting hobby full time. His friends and colleagues at Glen Fruin and A.R.L. wish him and Mrs. Norman a very long and happy retirement.

Retirement

A. C. LAW

Anthony Charles Law retired from the R.N.S.S. in May 1968 after 41 years in the scientific services of the Royal Navy for almost the whole period of which he was concerned with underwater acoustics.

Graduating with a Masters Degree at Aberdeen University his first employment was at that University as a junior lecturer under Sir George Paget Thomson in the Department of Natural Philosophy.

In 1927 Anthony Law was appointed a Junior Scientific Officer at H.M.S. *Osprey*, Portland, then the home of those Royal Navy Scientists associated with the development of Asdics (Sonar). His Christian name was soon abbreviated to 'Tony' and it was as 'Tony Law' he was known to many serving officers in the Royal and Commonwealth Navies, the U.S. Navy and to his scientific colleagues in France, Canada and the U.S.A.

From 1927 until 1940 he spent a considerable part of his time at sea in the experimental sea going tenders during which he carried out a very comprehensive survey of the Mediterranean Sea to determine the effect of temperature and salinity on acoustic propagation. He also succeeded in developing a pre-wetted chemically impregnated paper for electrically recording the incoming signals received by the Asdic equipment, and this proved to be of great value as an aid to the detection and classification of submarines.

On the outbreak of war in 1939 Tony Law's section was responsible for bringing into service Asdic equipment fitted in the many auxiliary vessels taken up for War service and also for the rapid translation of the latest experimental equipment into Naval use. In 1940 he moved to Fairlie on the Clyde coast as a founder member of His Majesty's Anti-Submarine Experimental Establishment. He combined trials at sea in the Establishment's experimental sea going tenders and in North Atlantic escort vessels with the development of new equipment and submarine countermeasures. Appointed a Principal Scientific Officer (Old Style) in 1943 he became deputy to the Chief Scientist in 1944, a position held until 1946 when the Establishment moved back to Portland and re-formed as H.M. Underwater Detection Establishment. In 1948 while still serving as deputy head of the Establishment he was seconded to the Torpedo Experimental Establishment to lead a special group formed to develop an advanced form of homing torpedo.

In 1951 with the rank of Deputy Chief Scientific Officer he returned to Portland as Chief Scientist, H.M.U.D.E. When the Underwater Weapons Establishment was formed in 1960 by the merger of the various establishments associated with underwater weapons Tony Law became one of the Chief Scientist's deputies responsible for the Sonar (former Asdics) department of the combined establishment. He was awarded the C.B.E. in the 1963 Birthday Honours List.

In May 1964 he took up the post of Scientific Adviser to the British Navy Staff in Washington D.C. and remained there until May 1968 when he returned to Portland to retire.

Book Reviews

Project Planning and Control—Simplified Critical Path Analysis. By D. C. Robertson. Pp. viii + 105. London. Heywood Books. 1967. Price 35s.

The basic function of Project Planning is to produce a realistic plan, which can become a management tool for control action. This book suggests that the advantages Critical Path Analysis has over the conventional bar chart approach are:

1. Some guarantee that the logic of the plan is correct.
2. Provision of relative weighting factors to each component activity of the plan.
3. A basis for the optimum use of materials and labour.

The emphasis is upon production projects and although it is suggested that the technique applies as well to research and development, experience shows that with such projects the evaluation of 'true' activity times has a large measure of uncertainty.

The author is strongly against the use of computers for this analysis and he advocates their use only in a plan of immense complexity.

The original concept had various trade names, one of which was PERT (Programme Evaluation Report Technique) but the principles are the same and all were concerned with the time control of a project. This was achieved by the interconnection of a logical sequence of activities (with their estimated duration) and events. The path of longest duration became the 'critical' path as it always controlled the project completion date.

Later derivations have introduced cost and labour and thus a critical path for cost and an optimum path for the deployment of the available labour force. This latter use of in the analysis has been termed 'resource levelling'.

The author emphasises the simplicity of the analysis, and the book can be read and understood in 2 - 3 hours. In the reviewer's opinion the book is over-priced, but it would seem to be compulsory reading for all project leaders.

Finally, the project leader who would think that this type of control provides the answers to all his major planning problems will be sadly mistaken unless he becomes fully aware that the quality of the analysis is directly dependent upon his ability to obtain realistic estimates of activity duration, cost and manpower requirements.

P. F. C. Griffiths

Silicon Controlled Rectifiers by Allan Lytel. Pp. 128. Slough. W. Foulsham & Co. Ltd. 1967. Price 21s.

This book is basically a collection of manufacturer's data and circuits, together with explanations in easy terms to assist the novice.

In Chapter 1, a definition of the silicon controlled rectifier is first given, followed immediately by a discussion of turn-on and turn-off methods, definitions of terminology and relevant characteristics. Then (and only

then) follows an explanation of the theory of operation. It seems a pity that many words are used here instead of a simple equation. The author also makes life more difficult for the student by arbitrarily introducing the concept of holes and electrons without first discussing semiconductor action.

Chapter 2 describes various methods of triggering the SCR, unfortunately omitting one of the better known systems in this country, *i.e.* the burst of pulses from a triggered blocking oscillator. Turn-off methods are also given in detail.

Chapters 3 and 4 concern methods of testing, specifications and characteristics for both typical devices and specific manufactured units.

The remaining sections of the book are devoted to the numerous applications of the controlled rectifier, *e.g.* static contactors, power control, ring counters, motor control, inverters, etc. Your reviewer would hesitate to agree with the publisher's note that the circuits "... are developed for your understanding". The practice adopted is to take a published circuit and give an explanation of its operation. In this, the author excels, although in his zeal to simplify matters, the correctness of his words leave a little to be desired. For example, page 106 has the extraordinary statement: "Capacitor C1 filters the field voltage to make it pure direct current".

There are many points which may be made regarding power supplies particularly where significant differences exist between practice in this country and America. However, the English publishers have obviously realised this handicap and have included a preliminary chapter which is a masterpiece of condensed information and advice for the English reader. Its author is to be congratulated for his clear exposition of vital matters (literally vital since they include personal safety).

Although this book is intended for the beginner, he would be well advised to use it only for information on types of circuits and should not attempt construction unless expert assistance is to hand. The experienced designer will find the book a useful *aide-memoire* parcularly when commencing new projects.

J. E. Etheridge

Digital Computer, A Practical Approach. By J. P. Marchant and D. Pegg. Pp. xiv + 200. London. Blackie & Sons Ltd. 1967. Price 27s. 6d.

The aim of this book is to give a broad view of computers and their applications, leavened by a "do-it-yourself" section. The jacket claims it "is particularly helpful to students in technical colleges and sixth forms of schools, and those taking training courses arranged by the computer industry."

An introduction includes a brief historical account from the Babbages to the present day.

Basic Ideas and the Binary System is the title of Chapter 1. Basic Ideas covers the reasons why computers work in binary terms and, surprisingly, punched tape, keyboard perforators, keyboard teleprinters, Pegasus II code, and parity, but the remainder of the chapter on binary arithmetic is clear and concise.

The main headings of Chapter 2, Component Parts of a Computer are What is a Program ? Output, An Outside Calculation (?), Calculating Facilities and Subroutines, Discrimination, Computer Speeds, The ICT 1900 Range of Computers, and English Electric Leo Marconi 'System 4'. Buried in the Section, What is a Program ?, there is a brief mention of Input, Storage, The Calculating and Arithmetic Section, and Control. Whether the chapter justifies the title is debatable, and it is certainly not the treatment of fundamentals one would expect in view of the intended class of reader.

Chaper 3, Logical Circuits, describes the logic functions and ways of achieving them electrically by means of relays or semiconductors, the aim being that the reader should build them himself. Chapter 4 covers Storage with more circuits for building. It is not clear why some items are relegated to the Appendix when they would be better included with the parent text. Thus although many diagrams have component values marked on them, some have values listed in the Appendix, one has both treatments whereas one has the component values on the drawing and the transistor types in the Appendix.

Chapter 5 describes two simple computers, both using relays and both reproduced at Bedford School, where are the two Authors. The simpler machine, Napier Briggs, is described in full. There are several versions of Simon, but only general information is given of this copyright design.

To illustrate Programming and Autocode, Chapter 6 shows how a simple computation would be programmed in machine code for Simon and for NHECTA 1 (Letchworth College of Technology), and in Pegasus Autocode.

Chapter 7, Further Electronic Circuits, includes enough information for the reader to construct a free-running multivibrator, a gated multivibrator and a monostable flip-flop. Their method of use in more complicated circuits such as digit delays, serial shift registers and adders is explained with block diagrams.

The Survey of Computer Applications, Chapter 8, covers scientific and technological applications, including critical path analysis and business applications.

A necessarily sketchy account of Computers and Automation occupies Chapter 9. The final chapter, Integrated Systems, deals with the possibility of total automation of production, including all the clerical-type activities as well as the mechanics of manufacture.

The Bibliography lists about 50 references, mostly textbooks, and there is a Glossary of Terms.

There are occasional irritating features such as the statement, "It should have become clear that . . . (p.73); a futile half-page introduction of the term cybernetics about which the most concrete statement is that Weiner's book sold 20,000 copies; the information that Fig. 4.12 "has important additions which are the capacitors X and Y", no explanation being given.

The printing and diagrams are clear. Only one typographical error was found (p.80—Post office type 300 relays).

The book is reasonably priced. It tries to cover a wide field and allots inadequate space to fundamentals for the readers at whom the book claims to be directed. The intention appears to be that this deficiency is made good by the descriptions of circuits for building, but the impression remains that it has not quite come off.

M. F. Wintle

Synchros and Servos. By Robert J. Brite and Carlo H. Fioranelli. Pp. 192. Slough. W. Foulsham & Co. Ltd. 1967. Price 35s.

This book is aimed at providing basic information about circuitry, function, application, maintenance and trouble shooting of synchros and servo mechanisms in a way which could easily be understood by a junior technician. It is written in the so-called programmed instruction format, each chapter being divided into small pieces of informaion. The text is designed around a two-page segment, facing pages including information on one or more concepts complete with two colour illustrations clarifying the word description used. Self

testing questions are included at the end of each two page segment, and summary of questions at the end of each chapter.

The first two chapters deal with data transmission and elementary control systems and the reader is given concise definitions amplified by clear diagrams. A few of the more common synchro devices are covered building up a clear mental picture of what these elements are and the meaning of the schematic symbols printed on the cases of the elements.

Chapter 3 covers the fundamentals of Synchro Devices and it starts with simple D.C. magnets and magnetization and in easy steps progresses to shaft positioning using A.C. voltages and magnetic induction. The next chapter deals with the function of synchro elements, how the output voltages are related to the shaft angular position for synchro generators and motors. The use of synchro differentials are taken next with a final two page segment on synchro control transformers. In Chapter 5 the various devices used as error detectors in servo systems are discussed. Potentiometers and E-type transformers are presented and their advantages and disadvantages explained. The utilization of synchro devices as error sensors in closed loop servo systems is covered, together with the uses and errors in coarse/fine synchro systems. The final part of this chapter dealts with the resolver, how it works and one use to which it can be put.

The functions of modulators and demodulators and some of the circuits used for these purposes are discussed and the reader is given an elementary introduction to servo amplifiers. The relationship between power output and type of amplifier is treated in a very elementary fashion. Thyratron and Magnetic amplifiers are taken next, together with a two-page explanation of the Ward Leonard rotating amplifier system. No mention is made of any other power amplifiers, and the reviewer feels that a few pages devoted to brief descriptions of hydraulic, metadyne, amplidyne and thyristor control would have been useful to the young reader.

Chapter 8 deals with rate measurement and gives a brief explanation of the operation of tacho generators and accelerometers. Some uses of the accelerometer are explained. Next three synchro-servo systems are mentioned together with a single page definition of an analogue computer, ending with a block diagram of a radar simulator.

The last chapter, and by far the most useful in the book, covers maintenance and fault finding in servo systems using chains of synchro elements. The method of setting up the zero of a synchro chain is discussed and an explanation of the diagnosis of twelve typical fault conditions is covered. There is a test paper at the end of the book which reviews the complete text and offers the reader a chance to test newly acquired knowledge.

The subject matter of this book has been covered in a number of other books and pamphlets published by the manufacturers of synchro and servo elements, but the collected information is presented in a new way which could be useful to a young person just starting to learn about these devices. The text is well printed and the illustrations are clear. As the book is of American origin the British reader has to take care in obtaining the precise meaning of the word descriptions and the method of instruction may not appeal to all readers.

R. Forse

General Topology. By Wolfgang Franz. Pp. ix × 156. George G. Harrap & Co. Ltd. 1965. Price 25s.

Over the centuries, by a gradual process of abstraction, algebra evolved from number arithmetic, to become eventually a generalized arithmetic. In a similar manner, but in a shorter time span, topology has emerged as a generalized geometry, embracing the Euclidean geometry we first learnt at school plus many other geometries developed in the current and last centuries. Topology is the science of geometrical space, and is concerned with analyzing the space concept and investigating the properties of general geometrical spaces, particularly those characteristic properties which are common to all spaces considered.

The numbers of real arithmetic can be manipulated according to certain basic operations or field laws. Algebra took these laws and applied them to more general systems which are defined axiomatically, and evolved the fundamental concepts of field, ring and group. Similarly, with the help of set theory and allied concepts, topology has progressed from the Euclidean space of schooldays to the fundamental concept of a general topological space.

The book consists of four parts, (a) The Theory of General Topological Spaces, (b) Special Classes of Spaces, (c) Metric Spaces and (d) Rudiments of Dimension Theory, (ten chapters in all). The author requires the reader to have a basic knowledge of the theory of sets and topics of modern algebra, and the basic formulae for set theory are at the back of the book. The approach throughout the entire book is of the pattern-definition or theorem, followed by proof. There is not a single exercise for the Student.

Consequently, whilst the book provides wide coverage of the subject with a rigorous approach, it cannot be recommended as a text book for the Honours Maths student. The latter needs worked examples and examples to work in order to absorb abstract concepts and manipulate them. On the other hand, the book is an excellent reference source, and this would constitute its main function in a College Library.

W. E. Silver

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